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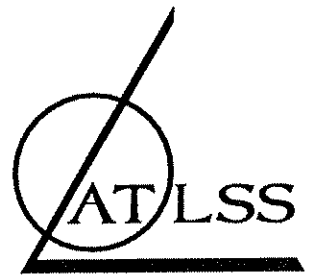
Ultrasonic Investigation of Floor Anchor Plate Welds to Determine Shear Capacity

Pete DeVere



ADVANCED TECHNOLOGY FOR
LARGE
STRUCTURAL SYSTEMS

Lehigh University

ULTRASONIC INVESTIGATION OF FLOOR ANCHOR PLATE WELDS TO DETERMINE SHEAR CAPACITY

by

Peter DeVere

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INTRODUCTION

The ATLSS Facility contains two distinct types of fixture-anchors, installed in two separate locations; wall anchors and floor anchors. This report focuses specifically on welds applied to the floor - anchor - weldment during fabrication.

The shear force " load path " was designed to transfer shear from test frames and structures into the floor through the floor - anchor - weldment shown in Figures 1 and 2 (see Drawing S-5, *Warner Burns Toan & Lunde* Project No. 84-3511). The anchor detail is comprised of three components:

a) A pair of 3 inch diameter bolts and lower anchor plate (Figures 3 & 4).

b) Four, 4 inch wide by 1 1/2 inch thick steel billets with shear studs (Figure 5).

c) Anchor plate, 2 1/2 inch thick by 26 inches long by 18 inches wide (Figure 6).

The anchor plate, bolts and billets of a typical floor anchor detail are shown in Figure 7. Drawings issued for construction specify continuous 1/2 inch fillet welds on each side of the billets, which are intended to transfer 500 Kips of shear from the anchor plate to the billets and into the floor slab.

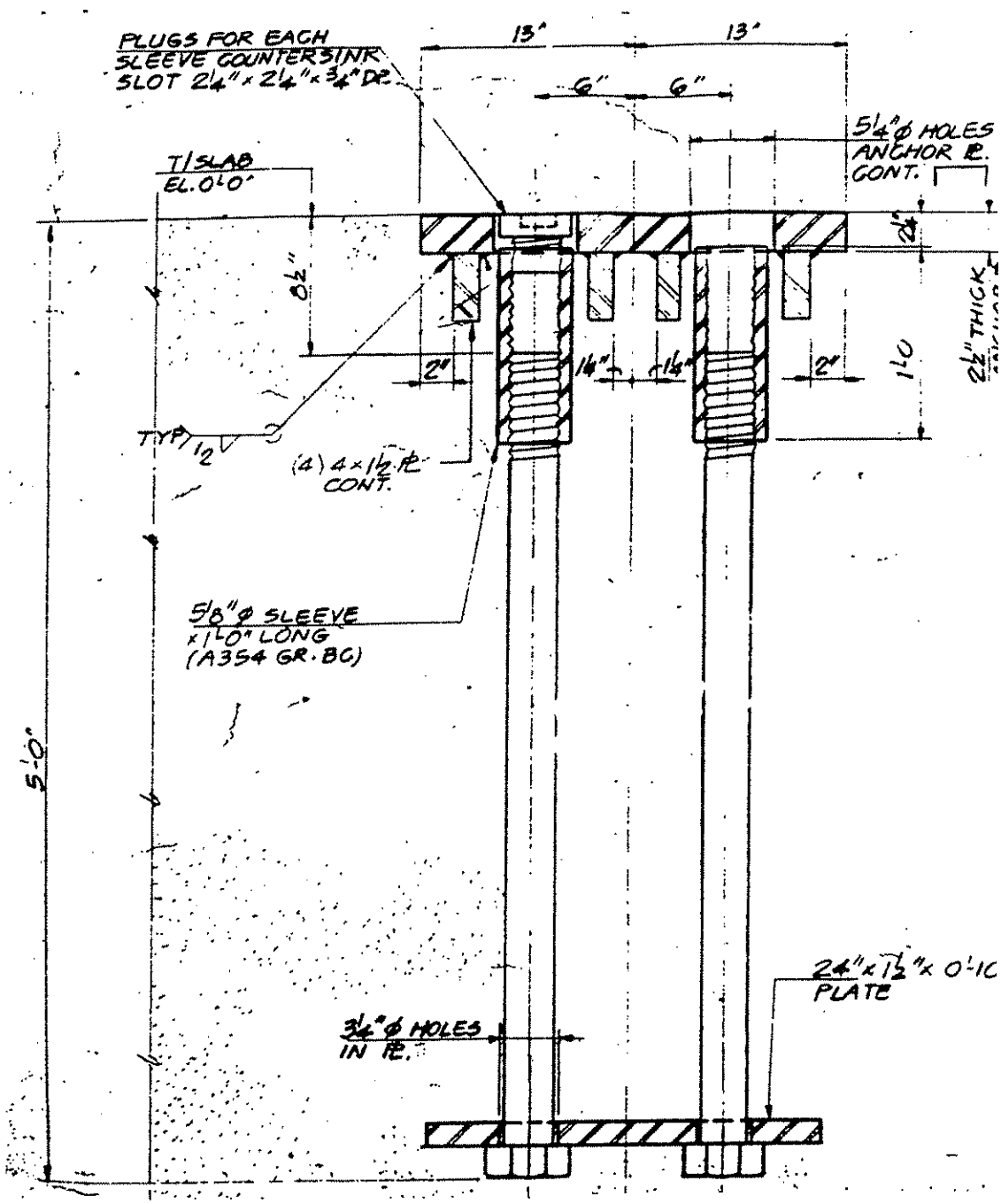
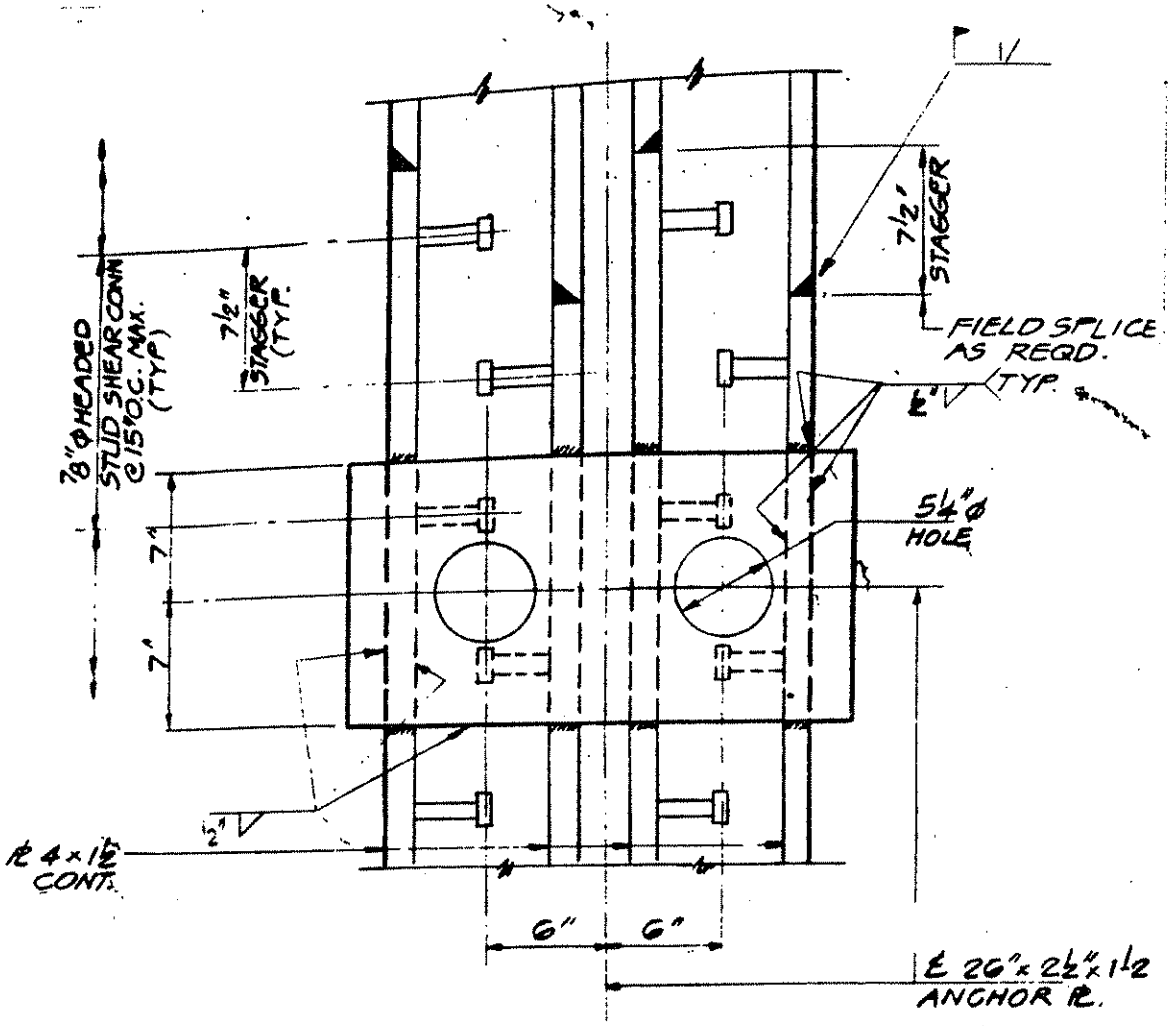


Figure 1
Elevation view of floor anchor detail;
Taken from drawings issued for construction.



PLAN

Figure 2
Plan view of anchor plate and billets which carry shear forces into the floor. Taken from drawings issued for construction.

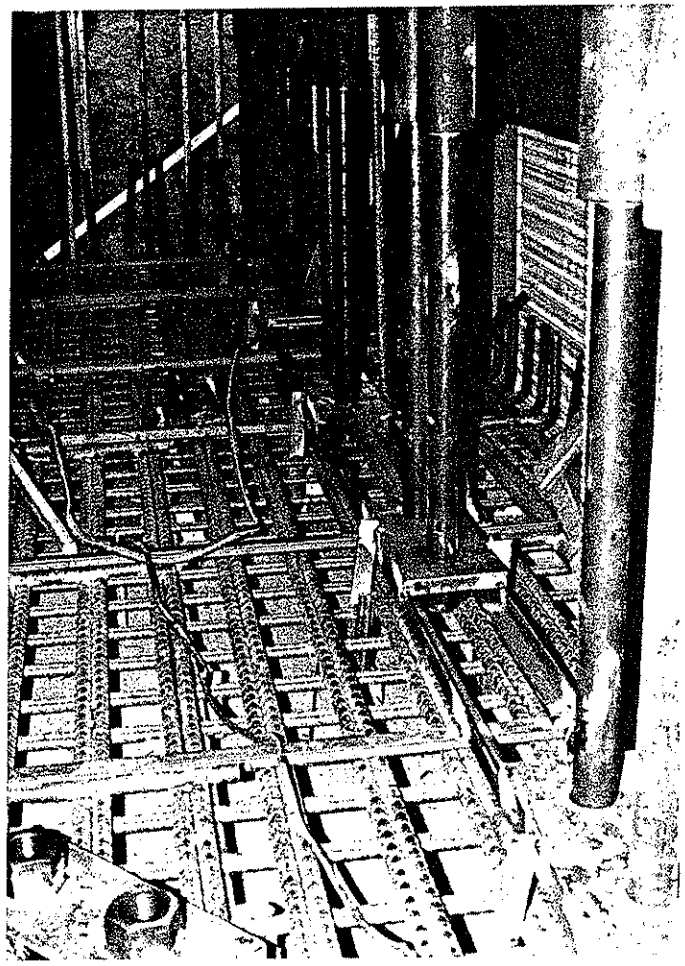


Figure 3

This photograph was taken looking toward the South-East corner of the 6 foot 3 inch deep floor section of cell No. 7.

The first "column" of floor anchor bolts and lower anchor plates are shown being supported on alignment fixtures fabricated with angles. It should be noted that the elevation of the lower anchor plate is the same throughout the entire floor area.

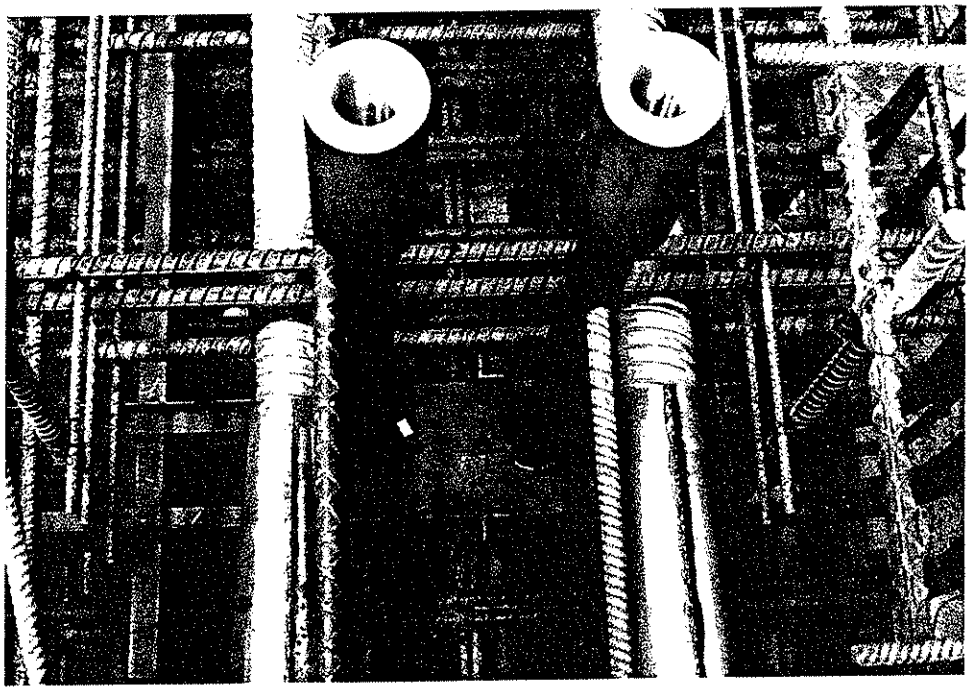


Figure 4
One anchor bolt-pair - lower plate fixture isolated from Figure 3.
Taken from the top of the concrete form-works at the South-end of the floor at Cell No. 7 looking North.

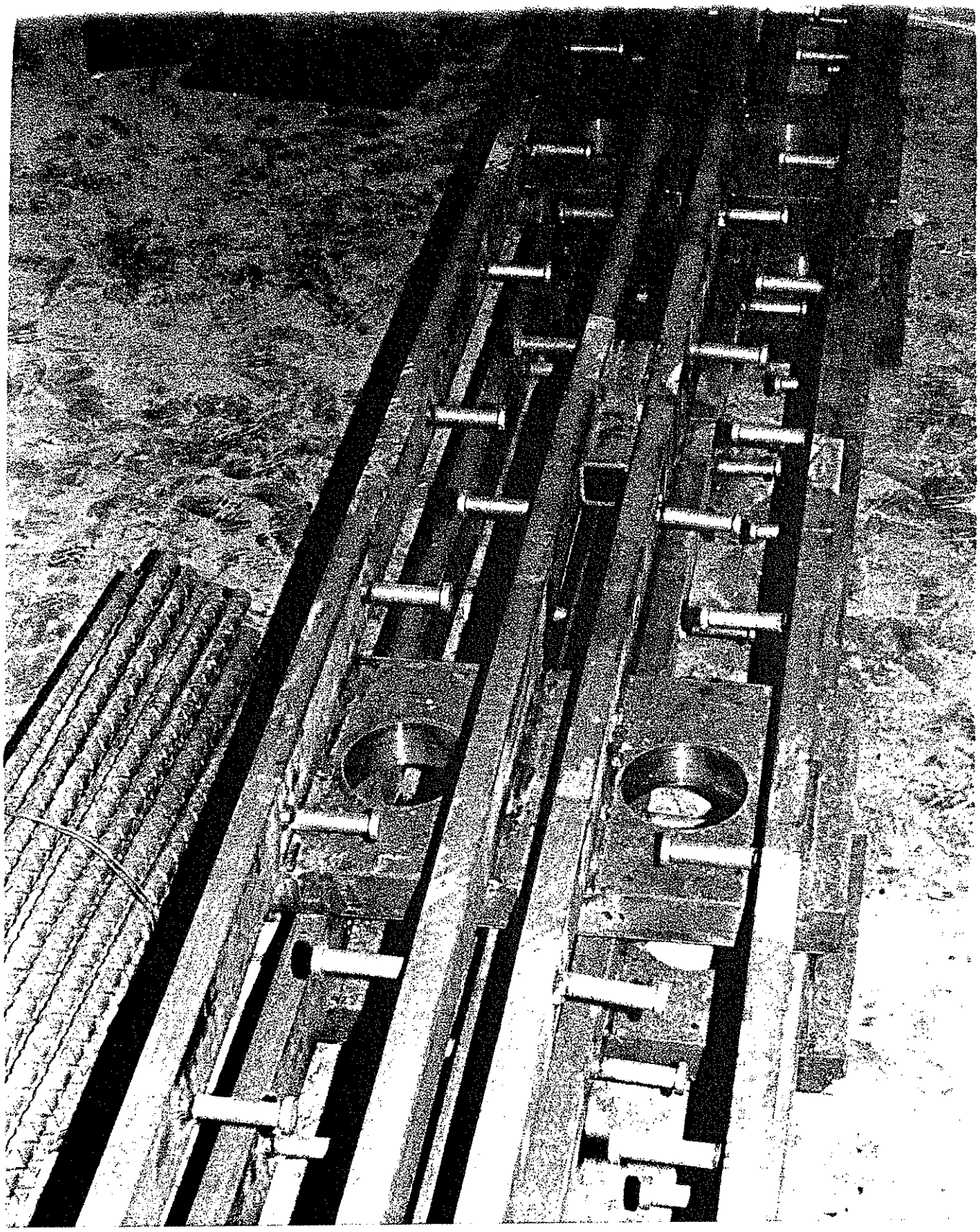


Figure 5

Floor anchor modules stored in the "H" Building lay-down area prior to installation. This photograph provides a perspective from the "under-side" of Figure 2; illustrating arrangement of the four, 1 1/2 inch wide by 4 inch deep billets, welded shear studs and 2 1/2 inch thick floor anchor plate with 5 1/4 inch diameter holes which accept the 5 1/8 inch diameter threaded sleeves.

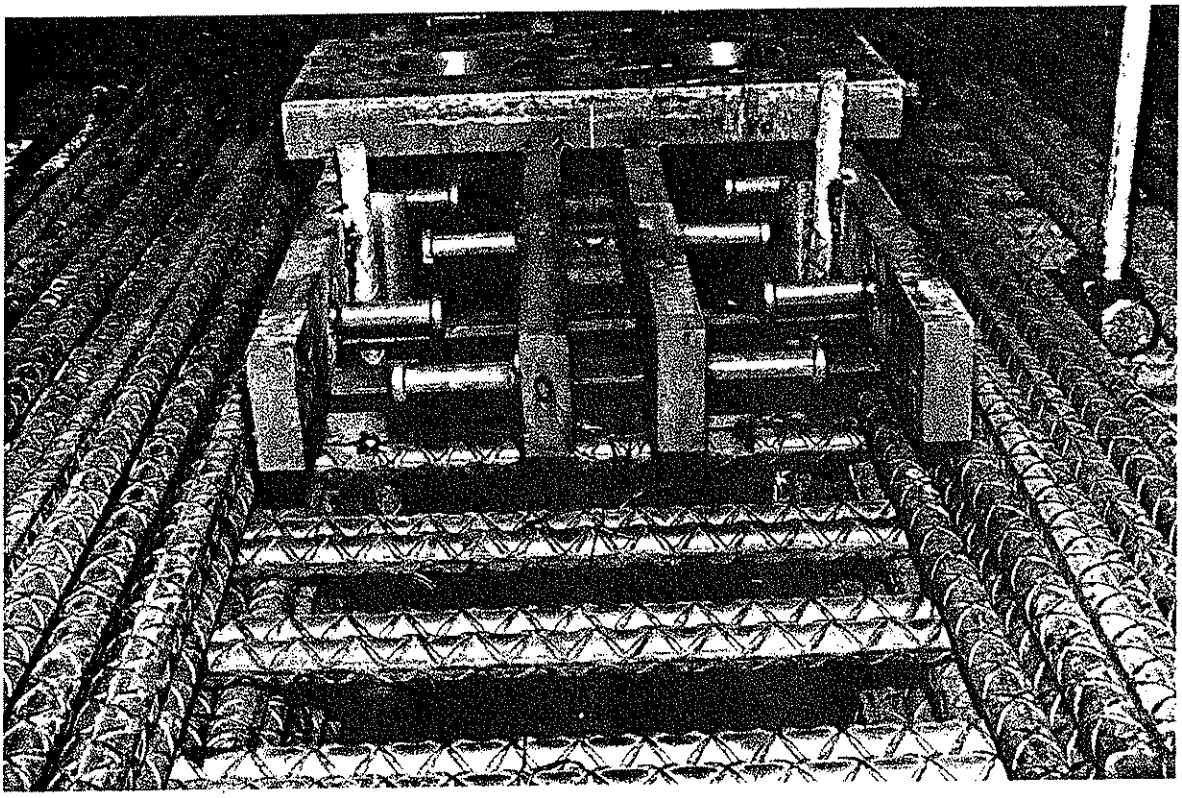


Figure 6
Three floor anchor plates are seen in the foreground.
Looking North and slightly West.
The fabrication sequence of anchor bolt -anchor plate fixture and billet-anchor-plate module is apparent.

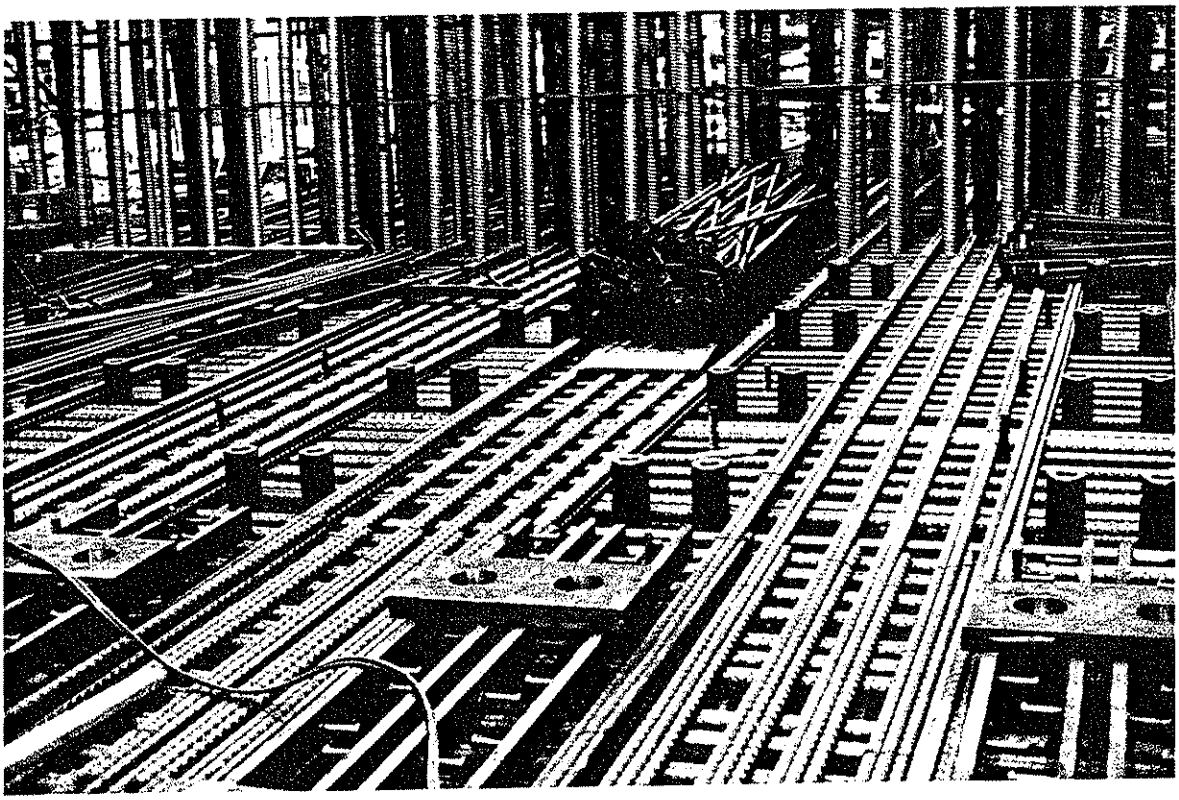


Figure 7
"End-on" longitudinal view (North-to-South) of one floor anchor point shown in Figure 6.

During construction of the ATLSS Facility, welds joining the 1 1/2 by 4 inch billets to the floor-anchor-plate were inspected by the writer (Figure 5). Visual inspection of this weldment (Figure 8) revealed non-continuous fillet welds were used and the size of those welds was smaller than the 1/2 inch size specified on Drawing S-5. This condition existed on all the floor-anchor modules located in the construction lay-down area within Building "H". Further inspection of module-weld-size was conducted using an AWS weld gauge the day before the first of three floor-slab concrete pours. All physically accessible modules were inspected with the AWS weld gauge. This portion of the inspection verified that all billet-anchor plate welds inspected in the "H" Building lay-down area were not continuous 1/2 inch fillet welds as specified by the construction drawings. The Construction Manager was notified of this apparent discrepancy the day before the first of three floor-slab concrete pours. This matter was not resolved during construction of the ATLSS Facility.

Subsequently, ATLSS contracted North American Inspection, Inc., Laurys Station, Pennsylvania, to verify size and quality of the floor anchor-plate-to-billet weldments using ultrasonic techniques. This ATLSS Report summarizes qualification of the ultrasonic test procedure and results of North American's investigation dated May 31, 1990; A facsimile of the cover letter to North American's report is included at the end of this report.

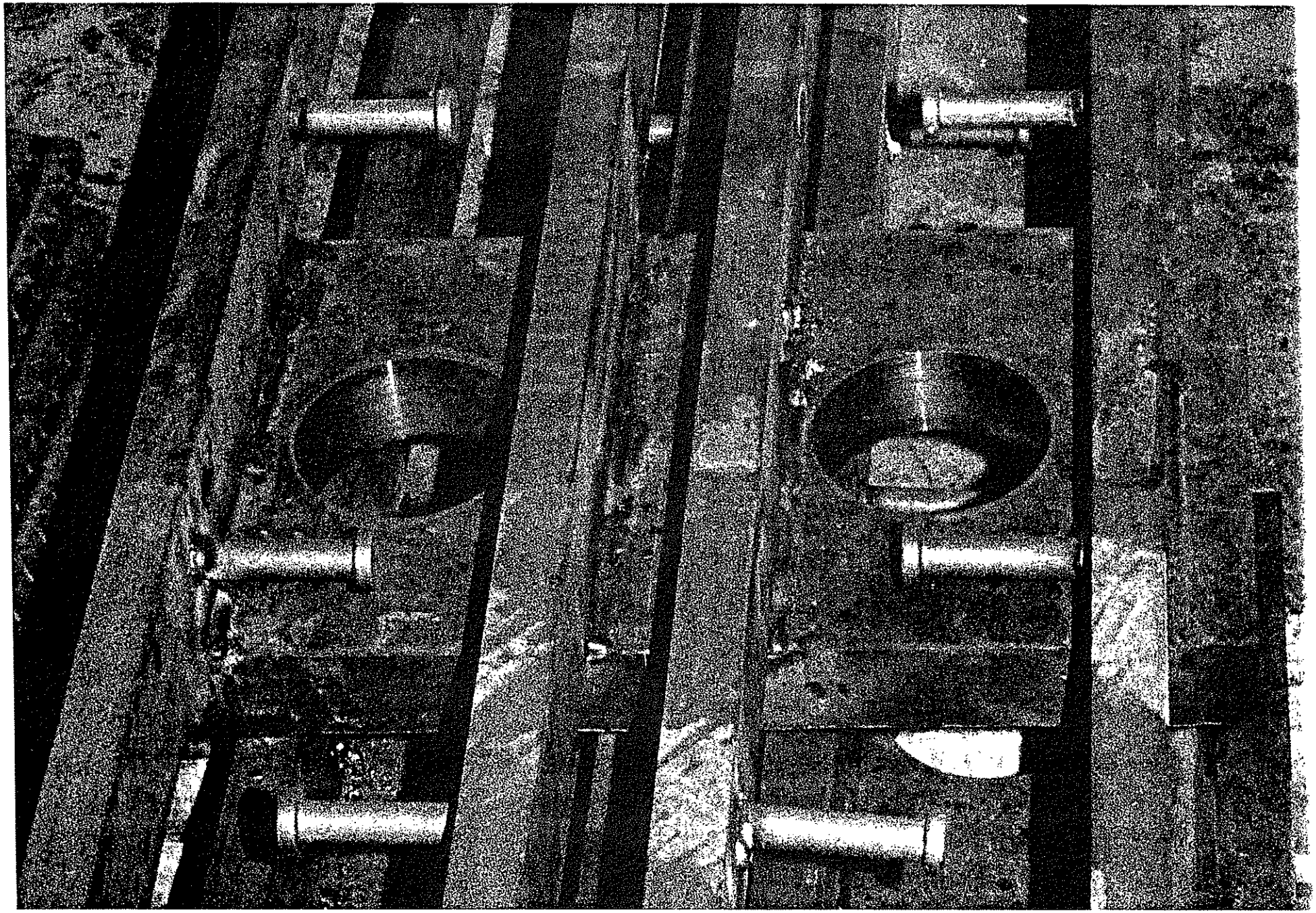


Figure 8

Enlargement of one billet-anchor-plate weldment from Figure 7.

C - Scan "Weldment Standard"

Verification of weld size and quality was established with the C-Scan method of ultrasonic test presentation. The purpose of our investigation was to establish the size and quality of the actual floor anchor plate-to-billet welds. This required a comparison of continuous and intermittent 1/2 inch fillet welds to welds of differing sizes and continuity. A full-scale "Standard" of the anchor plate-to-billet weldment was fabricated (Figure 9), to facilitate a C-Scan-baseline comparison of the actual weldment sizes to those specified on the issued-for-construction drawings.

The "Weldment Standard" consisted of a 2 1/2 inch thick "anchor plate" and two, 1 1/2 inch wide "billet bars" duplicating the essential variable of the floor anchor plate fixture; same thickness. To ensure that each weld applied to the "Weldment Standard" attained the highest quality possible, the components were prepared with extraordinary care. Each piece of the "Weldment Standard" was saw-cut and all mating and adjacent surfaces were milled. This ensured removal of all mill-scale and surface defects thus providing complete fit-up; enhanced weld quality and a "reflective surface" for ultrasound waves.

The size of the original "Weldment Standard" ,shown in Figure 9, was reduced so that its' weight would not restrict frequent lifting from one location to another. The final dimensions of the "Standard" were:

a) Two, 1 1/2 inch thick by 2 1/2 inch wide by 9 11/16 inch long, steel billets.

b) A 2 1/2 inch thick anchor plate; 9 11/16 inches long by 11 1/2 inches wide.

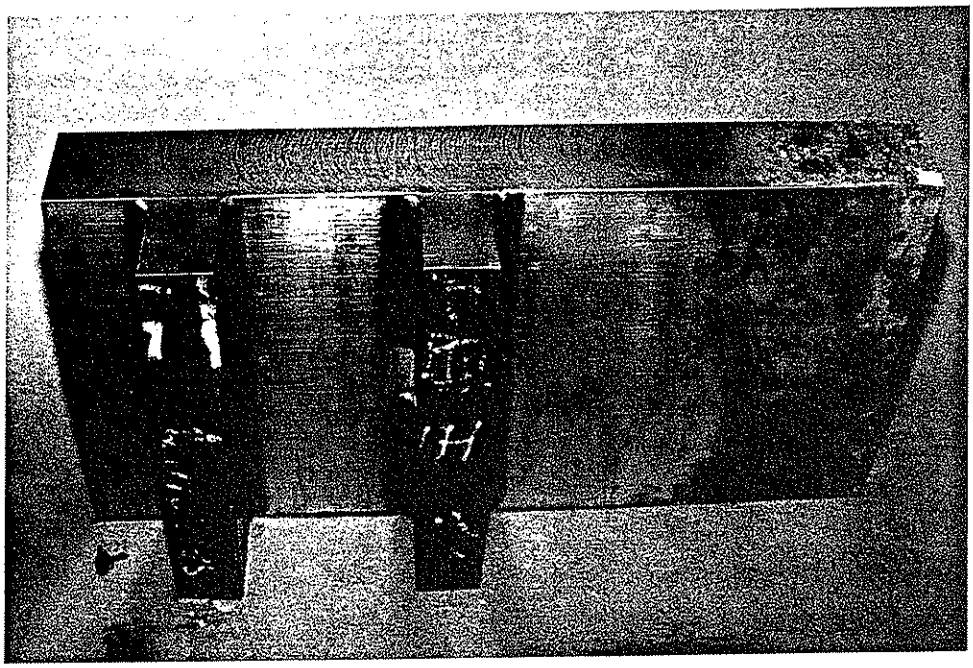


Figure 9

"Weldment Standard" Model upon completion.
Photograph shows 1 1/2 inch thick by 2 1/2 wide billets
welded to floor anchor plate facsimile.
The original anchor-plate "Standard" was
9 11/16 inches wide by 24 inches long.
Subsequently, 12 1/2 inches were saw-cut off the 24
inch length of the model anchor-plate.
Billet identification shown in black letters ("A" , "B")
was also die-stamped into the specimen for future use.

The model billets were welded to the plate with two weld sizes and types of continuity:

a) 1/4 inch continuous (Figures 10, & 10.1 Billet "A").

b) 1/4 inch intermittent (Figures 11, 11.1 & 11.2 Billet "A").

c) 1/2 inch continuous (Figures 10, & 10.2 Billet "B")

d) 1/2 inch intermittent (Figures 11, & 11.3 & 11.4 Billet "B")

These welds were produced using automatic gas shielded metal arc apparatus in the ATLSS Welding Laboratory.

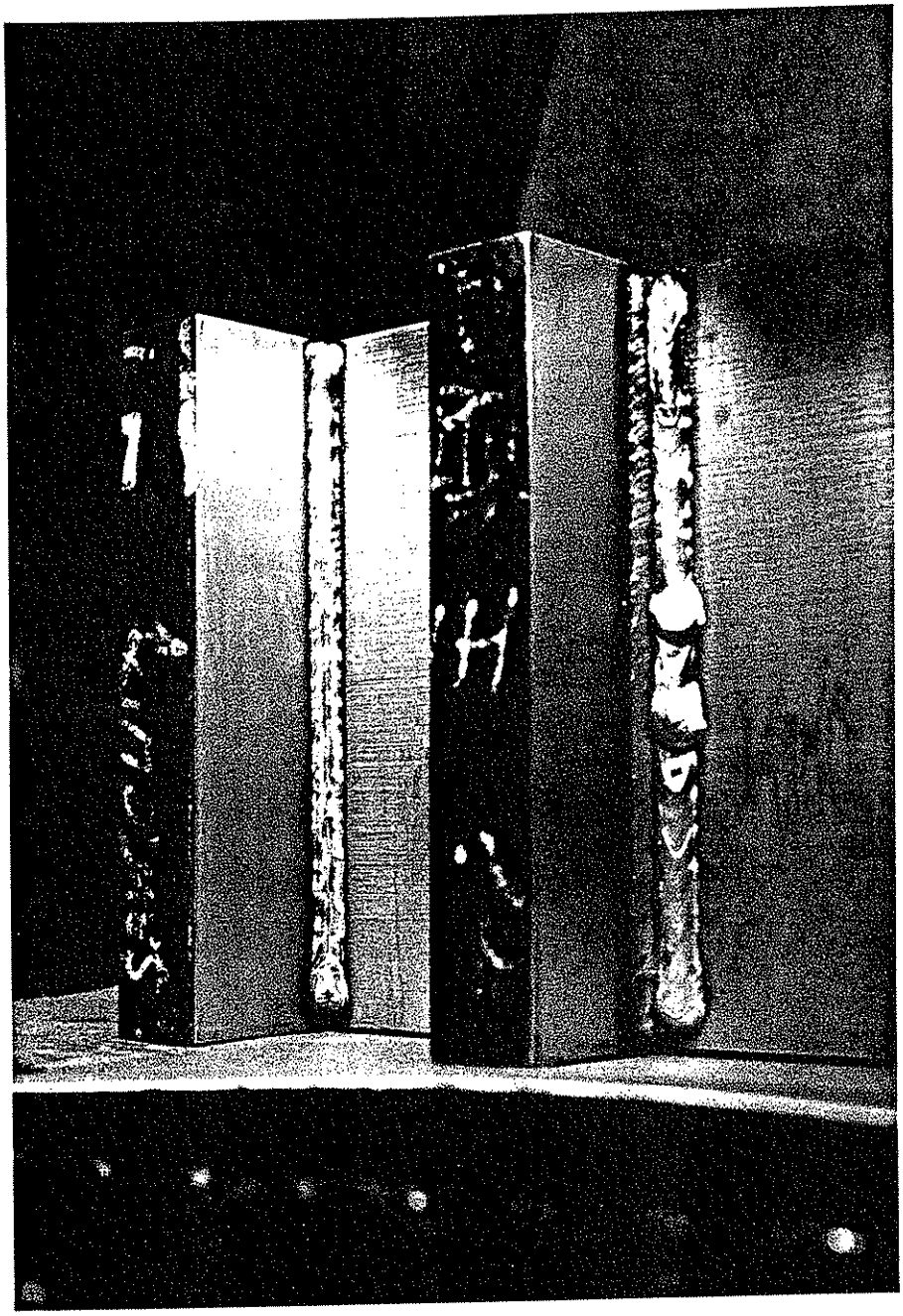


Figure 10
Right Side of the ""Weldment Standard"".
Billet "A" is attached to the anchor plate
with a 1/4 inch continuous weld.
(See Figure 10.1).
A 1/2 inch continuos weld is shown on Billet "B".
(See Figure 10.2).

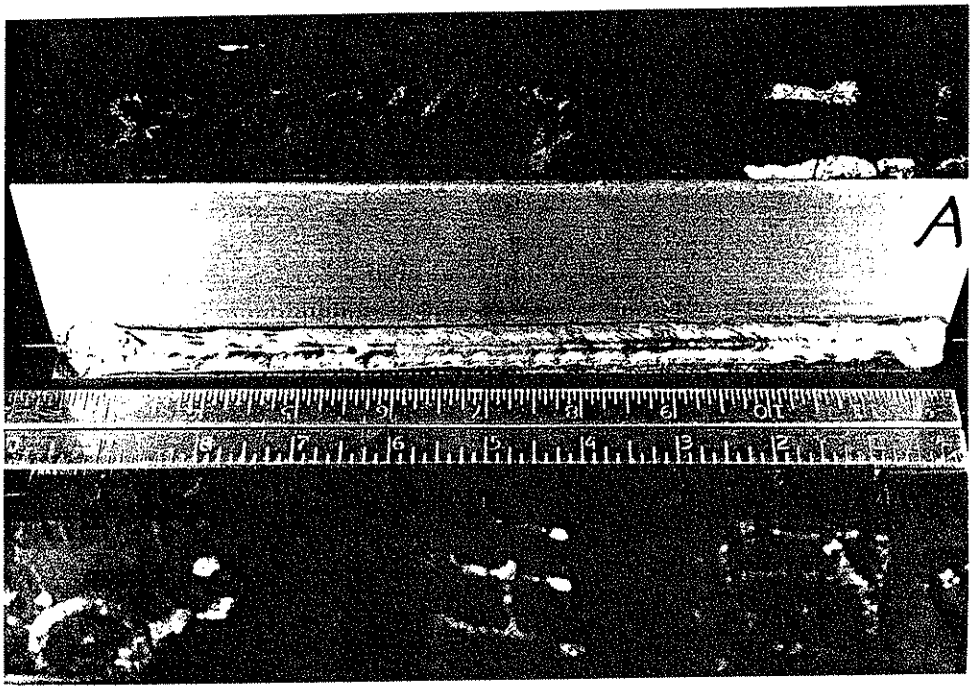


Figure 10.1

Right side of billet "A".

Photograph shows 1/4 inch continuos weld prior to cutting two C-Scan-verification sections. Steel rule is adjacent to the blue die-contrast area background and is matching the etched inch-line marks and die-stamped numbers from right to left.

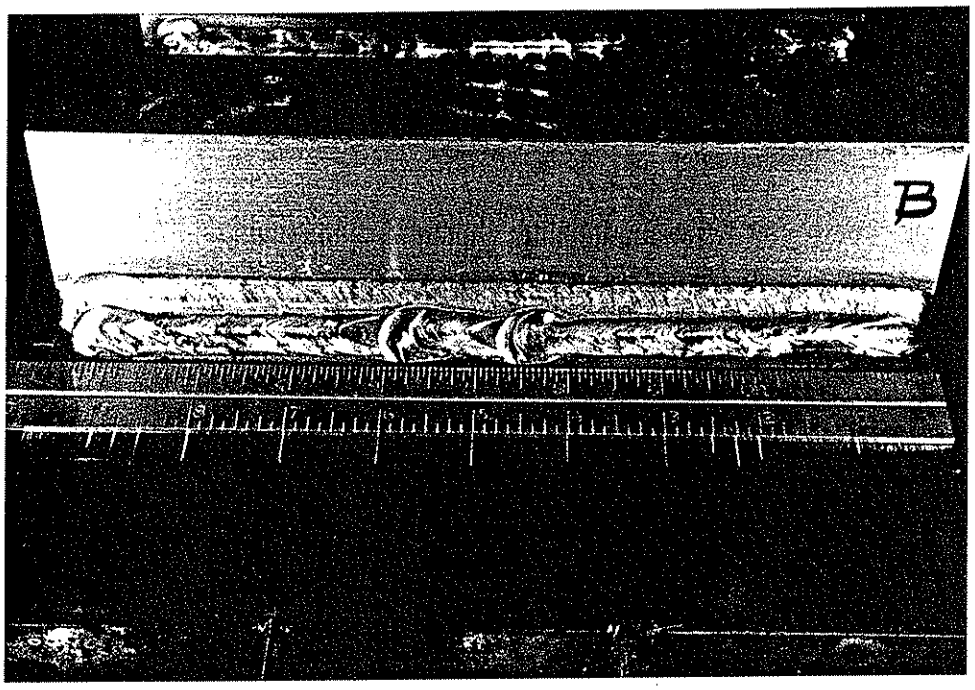


Figure 10.2

Right side of billet "B".

Photograph shows 1/2 inch continuous weld.
Etch marks in the blue die-contrast area are matched from right to left to steel rule marks starting at "1".

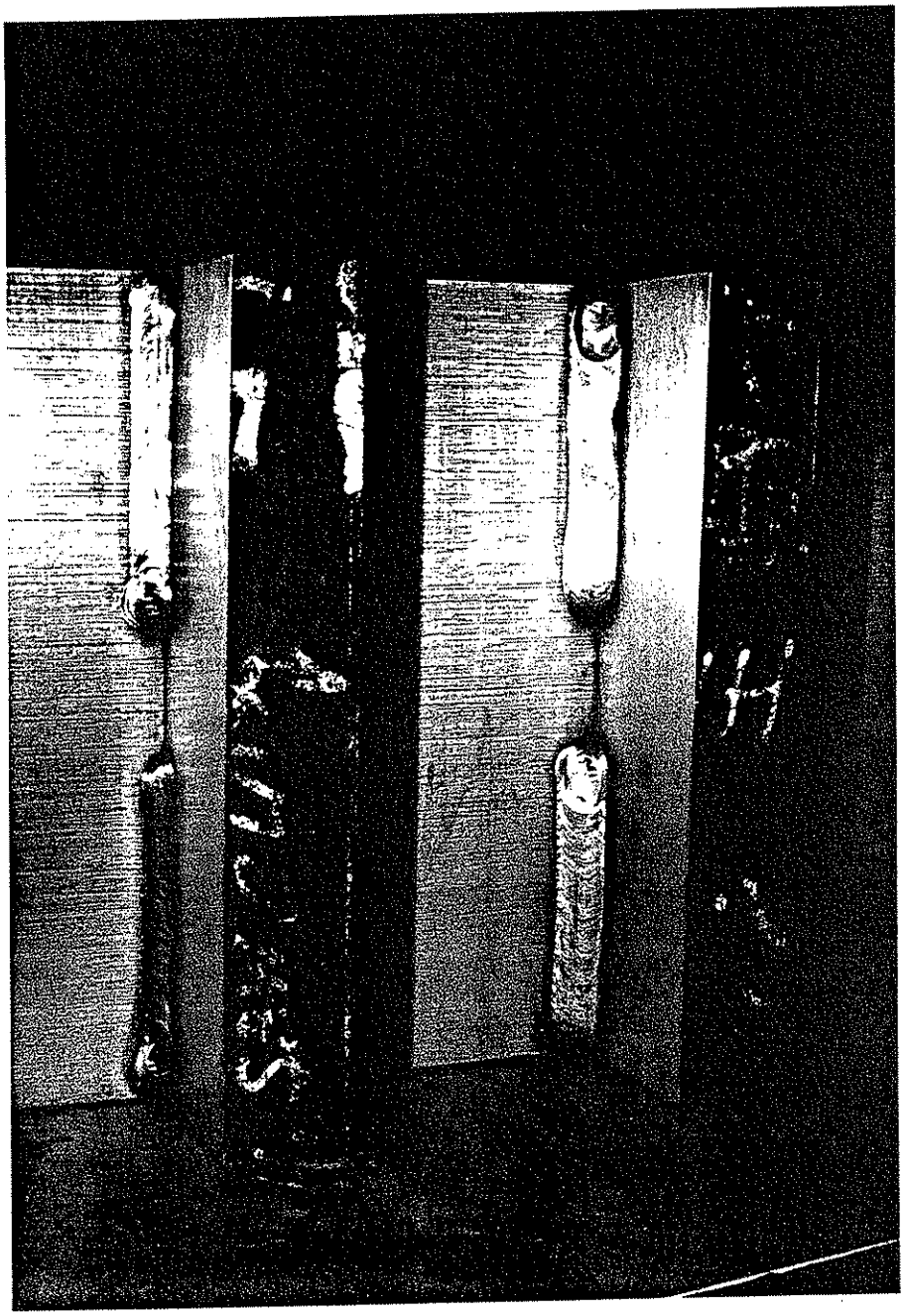


Figure 11

Left Side of "Weldment Standard".

Billet "A" is welded to the anchor plate with an intermittant 1/4 inch weld.
(See Figures 11.1 & 11.2).
An intermittant 1/2 inch weld attaches Billet "B" to the anchor plate.
(See Figures 11.3 & 11.4)

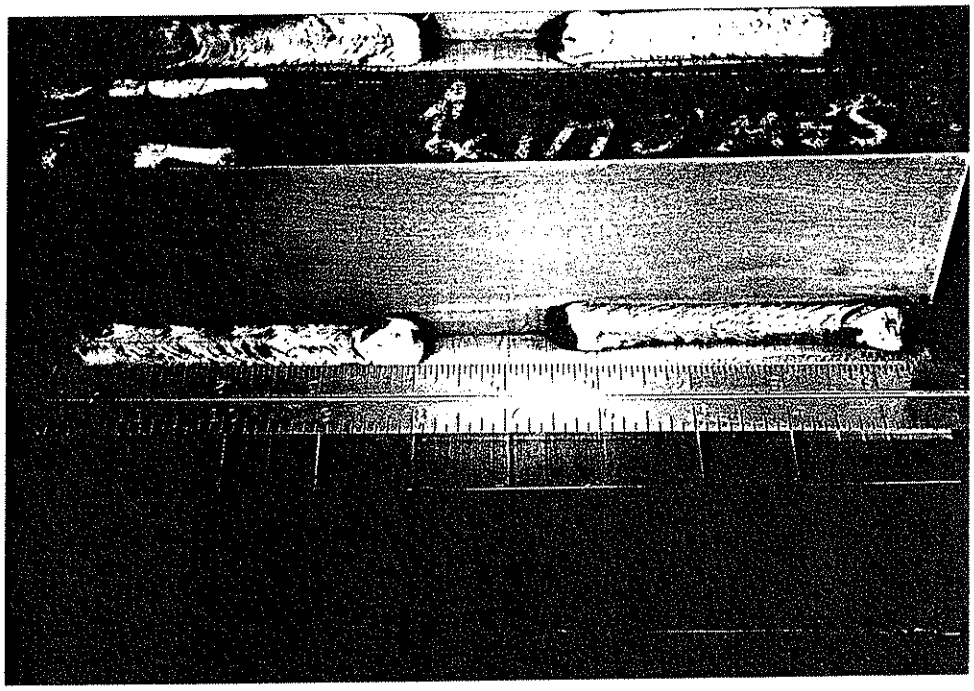


Figure 11.1

Billet "A".

Isolated view of 1/4 inch intermittent welds on left side of billet "A" as shown in Figure 11.

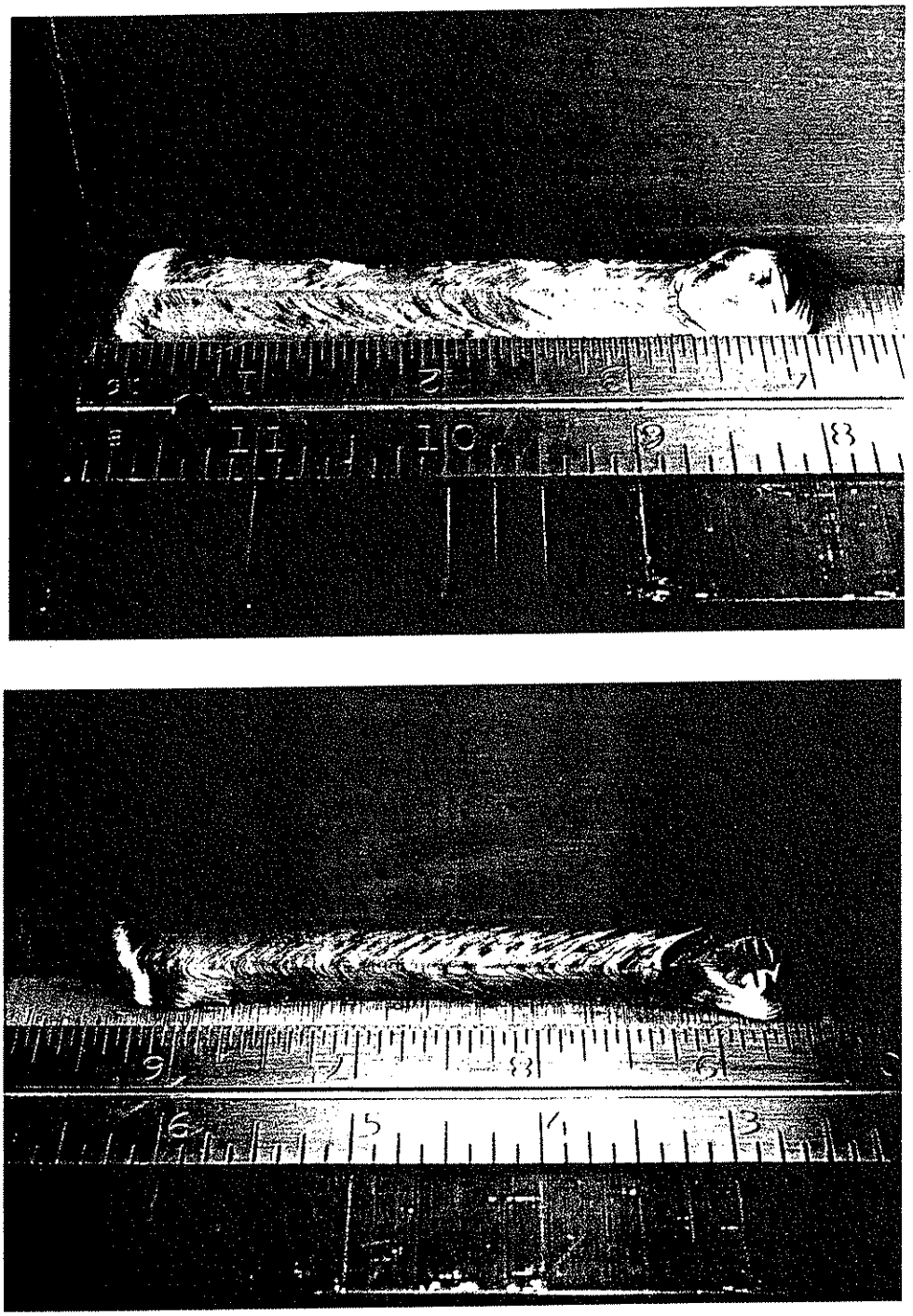


Figure 11.2
Two photographs; each isolating 1/4 inch intermittent welds on the left side of billet "A". These photographs are oriented top to bottom; duplicating the view of billet "A" in Figure 11.

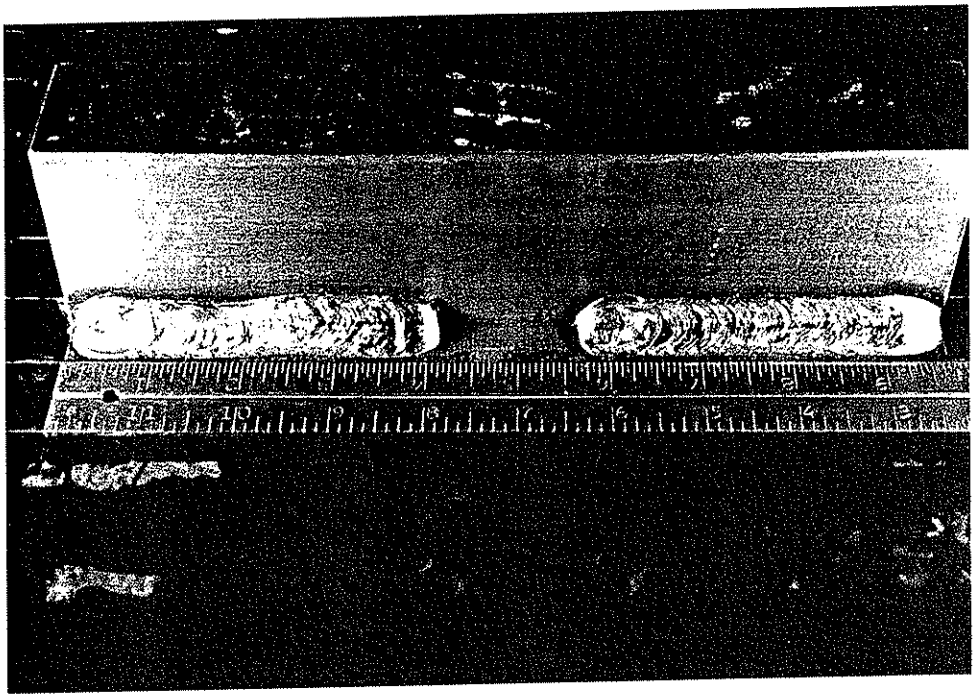


Figure 11.3

Billet "B".

Isolated view of 1/2 inch intermittent welds on left side of billet "B" as shown in Figure 11.

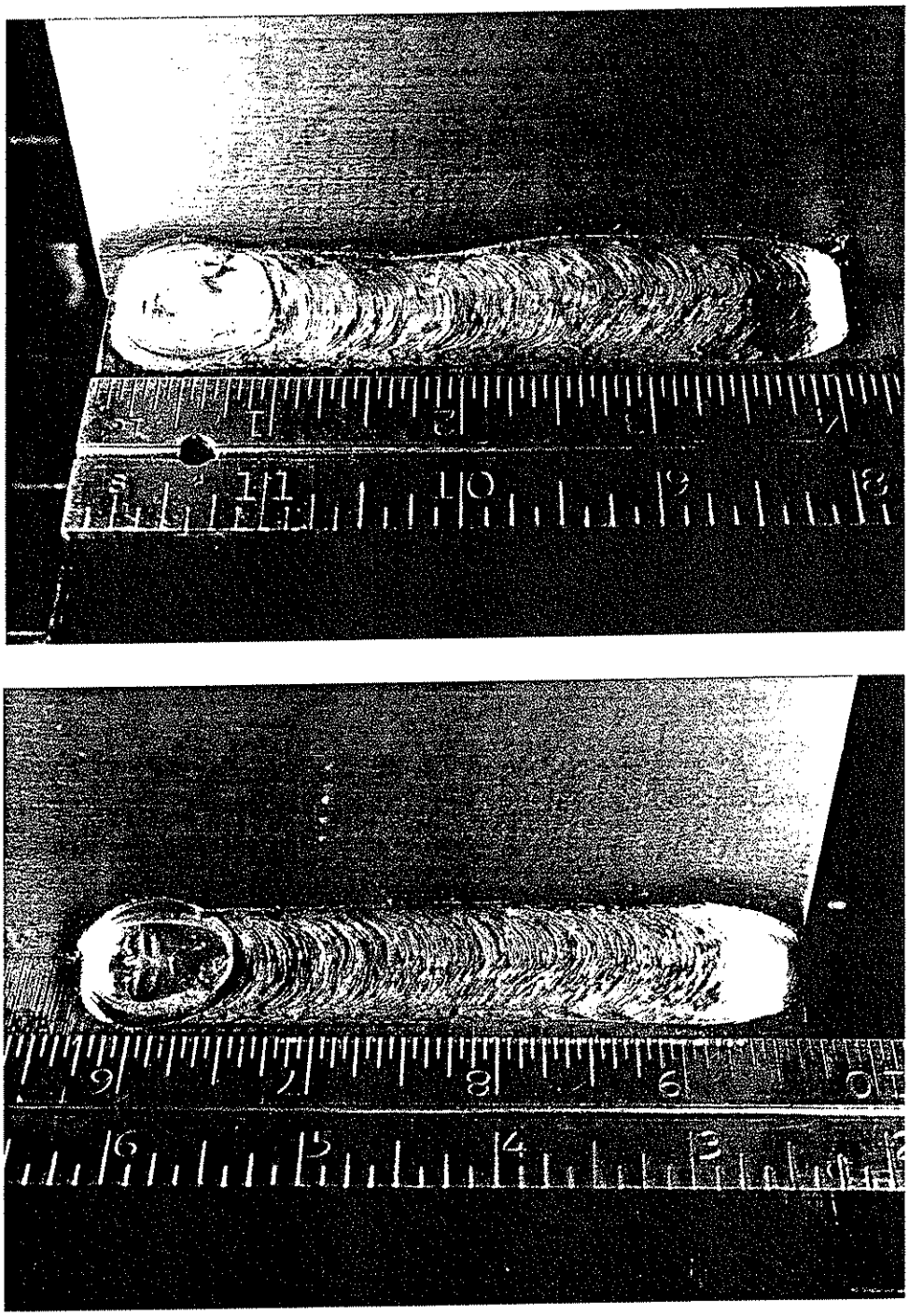


Figure 11.4

Two photographs; each isolating 1/2 inch intermittant welds on the left side of billet "B". These photgraphs are oriented "top-to-bottom"; duplicating the view of billet "B" in Figure 11.

Qualification of C-Scan Protocol

Weld-size comparison charts were produced by submerging the standard in a water couplant; then scanning the top-side plate using the C-Scan method of ultrasonic presentation, (Figure 12). The C-Scan apparatus uses an automated transducer-bridge which indexes forward 0.025 inch after completing a full width scan. Thus a 1 inch long weld area is scanned 40 separate times. Each dark line-indication in Figure 12 represents a loss of back reflection due to the presence of metal fusion as a result of weld-process heat (illustrated in figure 13). During establishment of a testing protocol, a gain-setting of 5 to 7 db above 100% back reflection was found to give reliable results. Further qualification of the C-Scan protocol was accomplished by measuring actual weld profiles in the standard to the loss of back reflection patterns on its' C-Scan chart record. This was achieved by saw cutting the original "Weldment Standard" at predetermined strip chart locations; measuring the actual-effective weld sizes of the standard and comparing these sizes to line-indications on the standards' C-Scan strip charts. Once C-Scan charts of the "Weldment Standard" were developed, the sizes of the floor anchor plate-to-billet welds were determined.

The as-built weld sizes for each billet-to-plate weld was recorded as line-indications on the strip-charts. The process of identifying welds that are undersized and of unacceptable quality is demonstrated in Figure 14. Figure 14 illustrates how size and quality indications manifest themselves on a C-Scan strip chart. The left-hand portion of the figure shows a 1/2 inch weld C-Scan indication taken from the "Weldment Standard". The right-hand portion shows an actual weld indication taken from plate C15; R5; bar 2. The reduced weld size of C15;R5;bar2 is apparent. Quality of this weld is determined with help from Figures 14 & 15. Looking at the left portion of Figure 14 at the

C-Scan line-indications of a "Standard" 1/2 inch fillet weld. Note that each line indication is continuous from top-to-bottom. The right-hand protion of Figure 14 has approximately 14 "white holes" among the weld line-indications of C15;R5;bar 2. By tracing a line-indication at one of these "white holes" from top-to-bottom, you find that; at these particular locations, lines-indications are not continuous. Discontinuity of a C-Scan line-indication is evidence that lack of penetration exists between the weld metal and base metal. This is further illustrated by Figure 15; which shows a sonic wave returning to the transducer after reflecting off of the anchor plate. Sonic waves hitting an acceptable portion of a weld do not return to the transducer, thus no line indication. The weld sizes and quality of twenty-one floor anchor plate weldments were determined by North American Inspection in the same manner.

In order to ensure reproducibility of test results, the standard was measured and a photographic record taken before comparison-sections were cut. First, blue contrast ink was applied to billet-side of the anchor plate. The "Weldment Standard" was then measured and etched with "inch-markers." The "0" inch mark designated the "front end" and the "9" inch mark designated the "back end." Figure 10.1, shows the right side of billet "A" and its' continuous 1/4 inch weld. Figure 10.2 shows the continuos 1/2 weld on the right side of billet "B" (reference Figure 10). Additional inch marks were etched into the left side of the "standard" as shown in Figures 11.1 and 11.2. Photographic close-ups of each intermittent weld are also presented in Figures 11.3 and 11.4 to facilitate traceability of locations on the "standard".

After inch markers were scribed on the edges , the 9 1/2 inch long "standard" was saw-cut in two predetermined locations initially measured on its' C-Scan strip chart. Figure 14 illustrates the first cut

was made 2 3/8 inches from the "front-end" and the second cut was 1 inch from the "back-end". Each billet was die-stamped before cutting and subsequent to separation of the sections from the original standard.

Each section was belt-sanded prior to etching with a nitric acid-water solution in the ATLSS Welding Laboratory. The writer hopes that apologies are accepted for the poor quality of etching shown in the accompanying photographs. The "standard-sections" were too large to fit the milling machines located in Fritz Laboratory and the belt sander would safely accept the section in only one position; across the 11 1/2 inch width which is also parallel to the mating line of the billet and anchor plate.

The 2 3/4 inch and 1 inch thick sections were utilized by North American Inspection as part of the test protocol calibration and subsequently by the writer for reference. The remaining "standard" was stored in the ATLSS machine shop of Building "H." Photographic records were taken of billets "A" and "B" after belt-sanding and etching. These are presented as Figures 16 through 23 on the following pages.

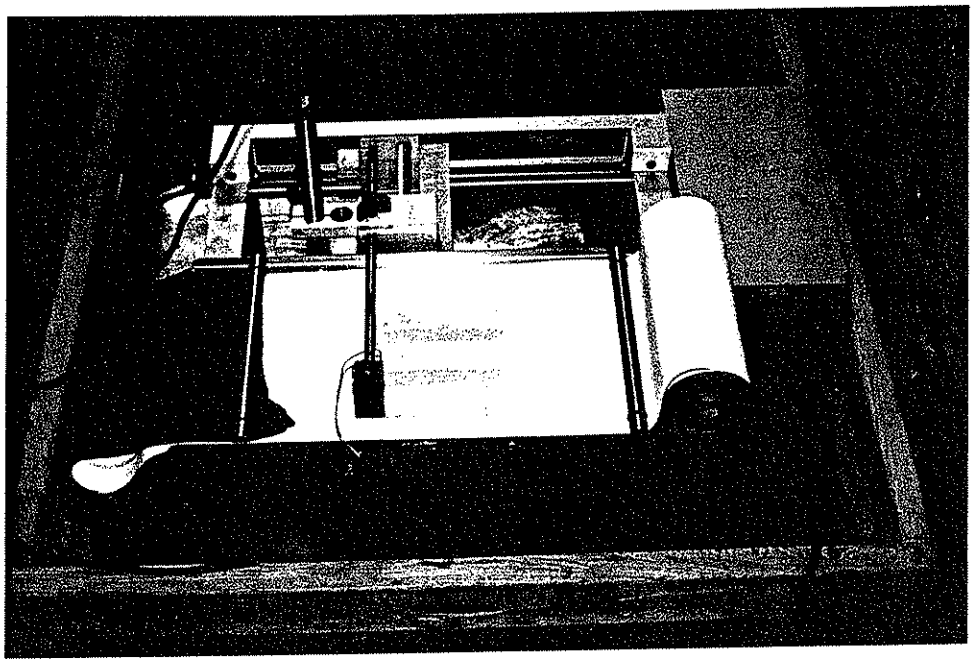


Figure 12

North American Inspection's C - Scan set-up and apparatus during investigation of floor anchor plate weld sizes. Two dark line-indications are visible in the upper portion of the paper strip. These are being electrostactically placed onto the strip chart from right to left. The C-Scan apparatus "etches" line-indications upon loss of sonic wave reflection back to the transducer. The two upper line indications are weld size indications. The bottom line indication shows the edge of the anchor plate.

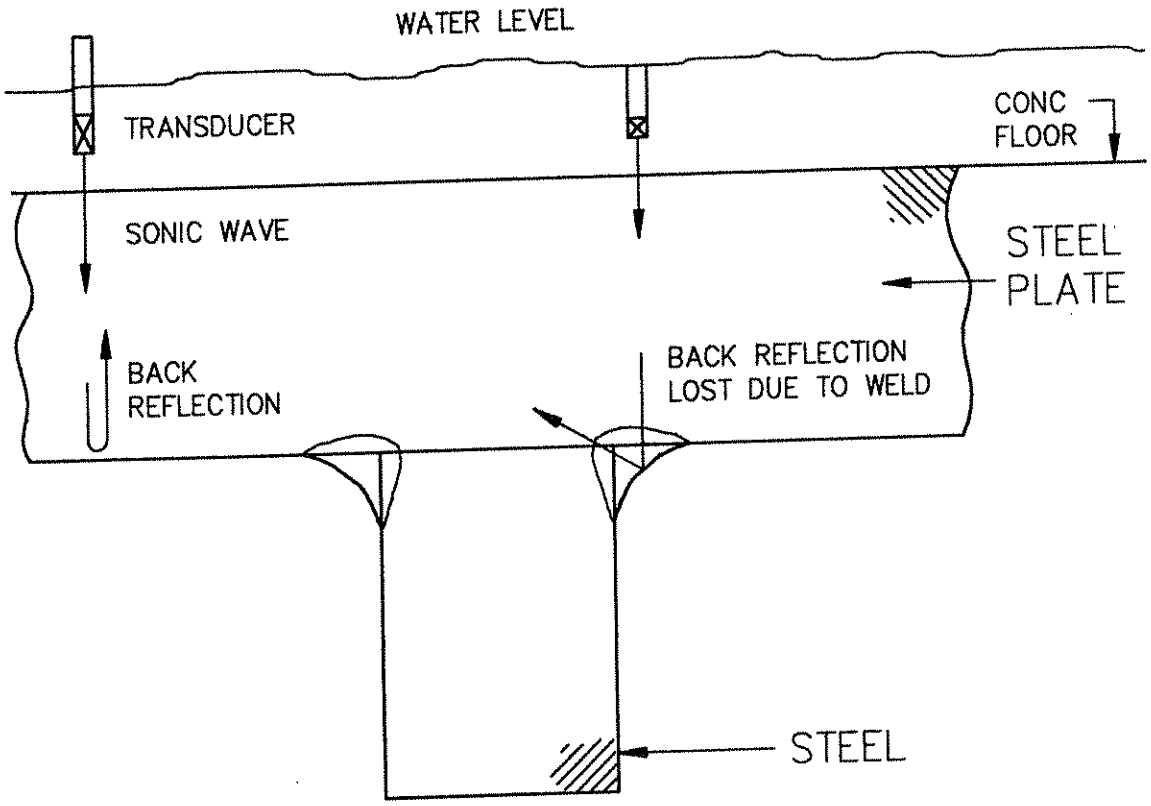
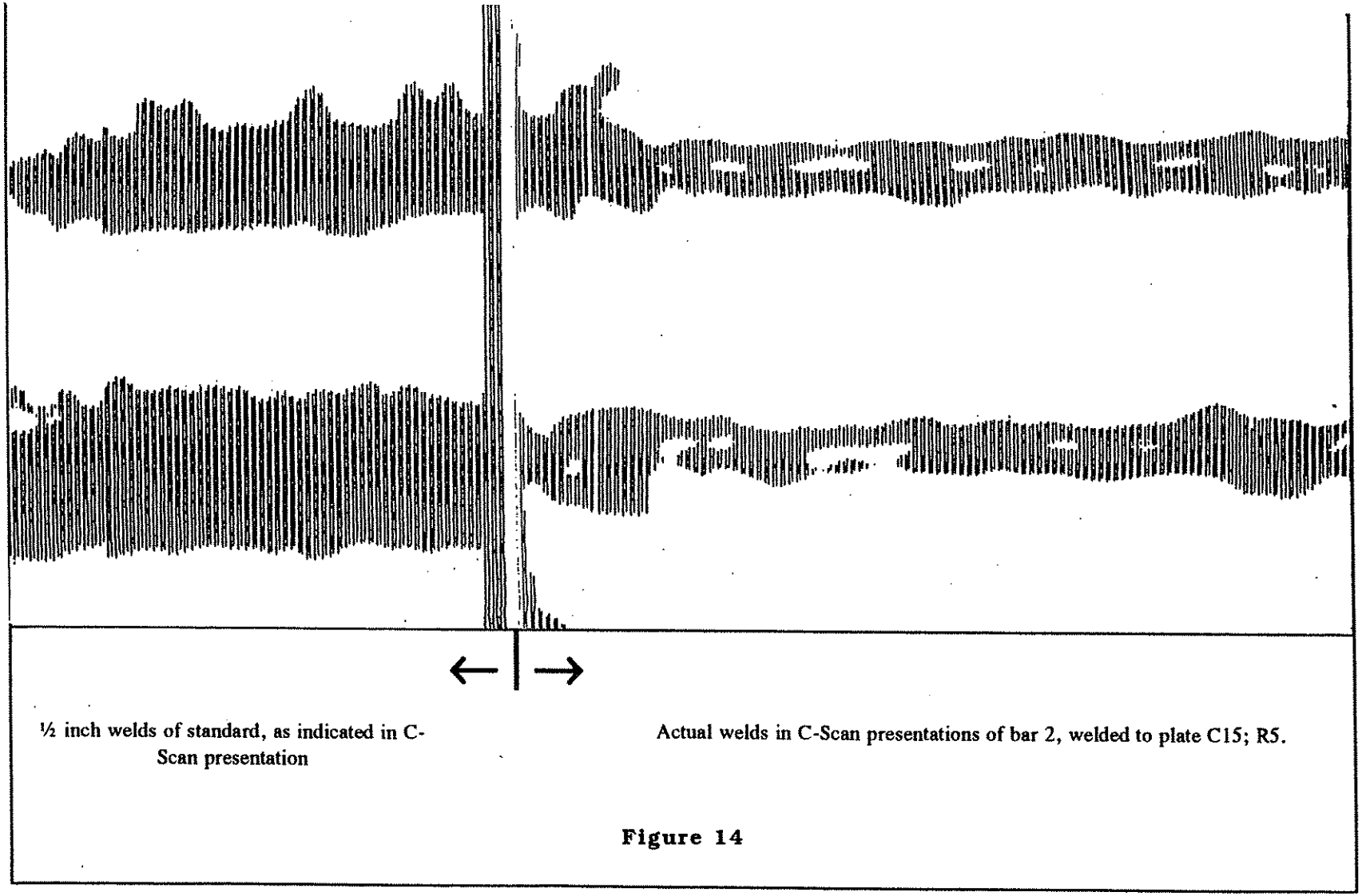


Figure 13

Schematic representation of sonic wave returning to the transducer after back-reflection. Loss of back reflection is demonstrated when sonic wave encounters edge of a weld.



½ inch welds of standard, as indicated in C-Scan presentation

Actual welds in C-Scan presentations of bar 2, welded to plate C15; R5.

Figure 14

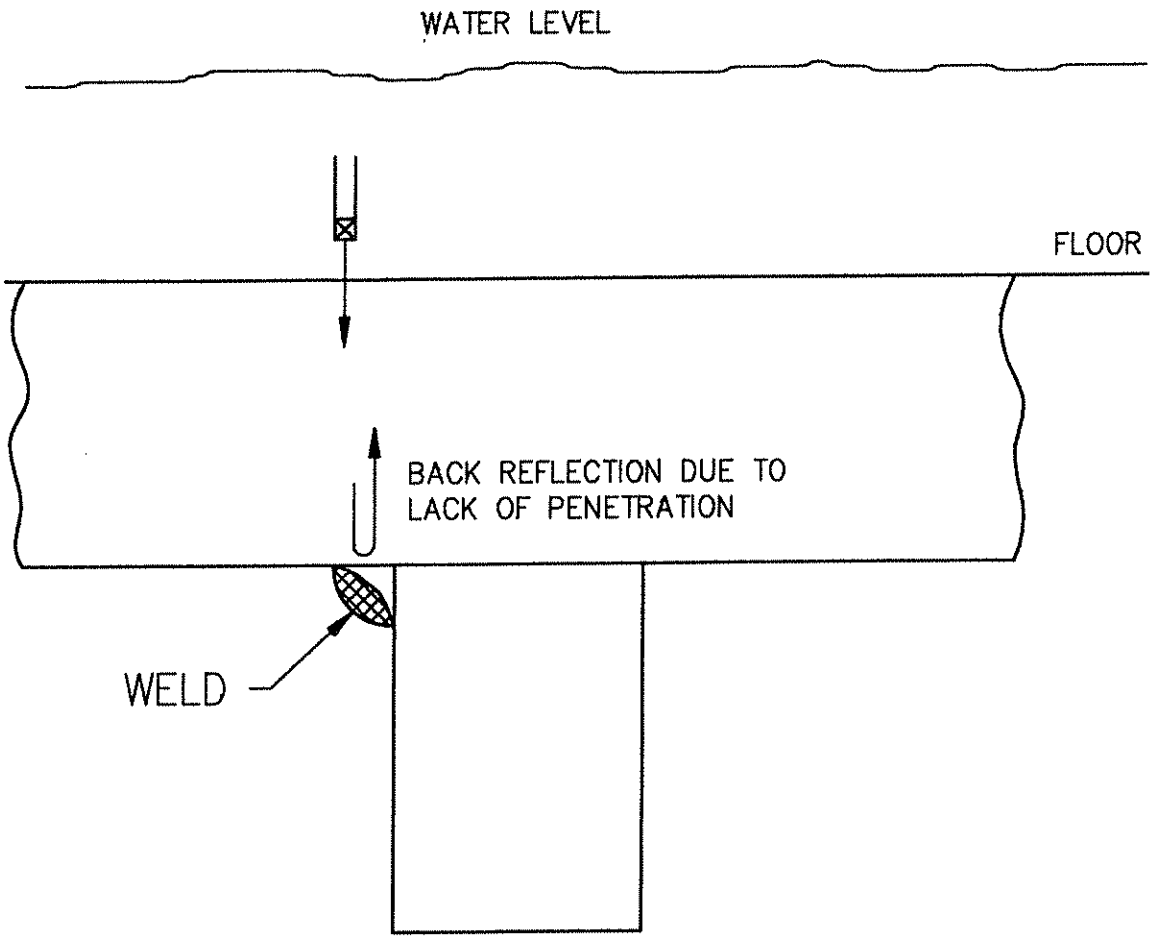


Figure 15

Illustration of a weld defect-indication manifested by the C-Scan method of ultrasonic presentation

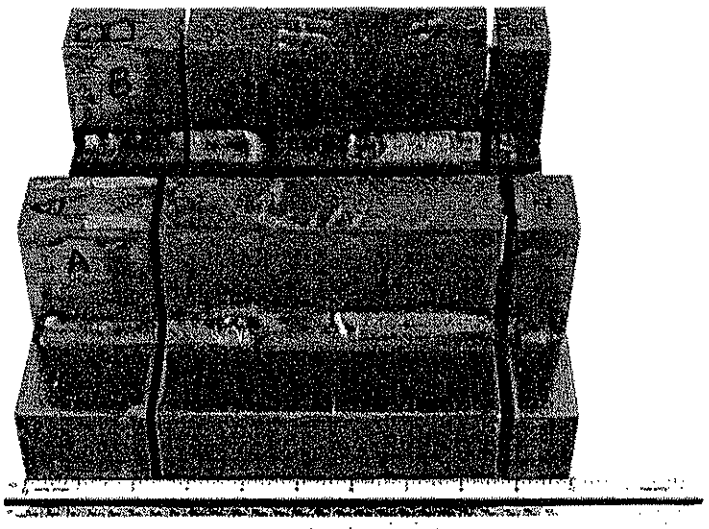


Figure 16
Identification of "Weldment Standard"
Photograph taken after saw-cutting sections.
The Front-end is at the "0" inch mark on the scale.

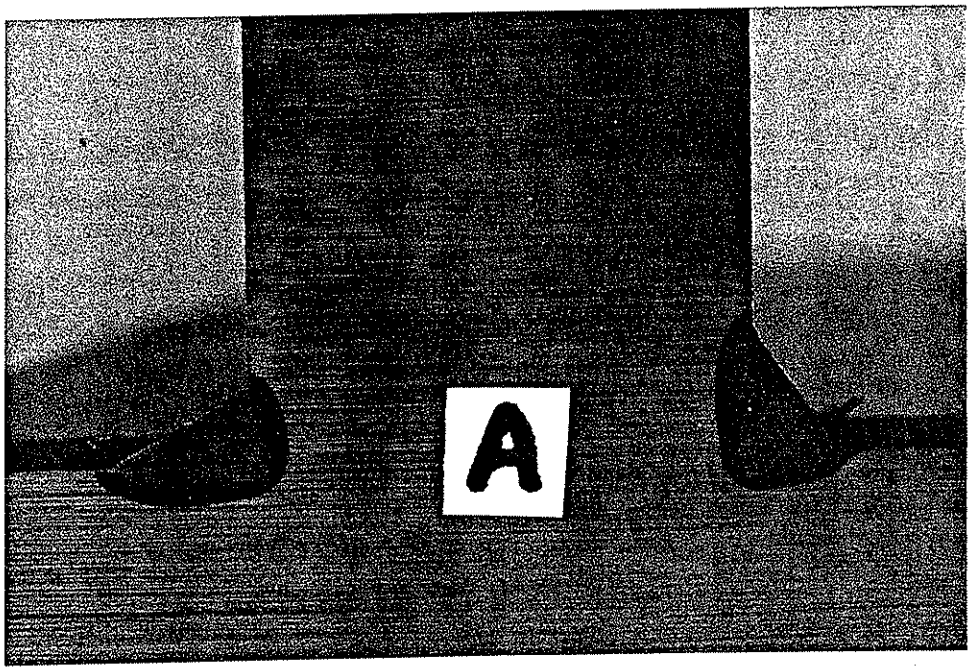


Figure 17

"Weldment Standard" Section; 2 3/8 inches from "front-end".

Billet "A" weldment

Left: 1/4 inch intermittent.

Right: 1/4 inch continuous.

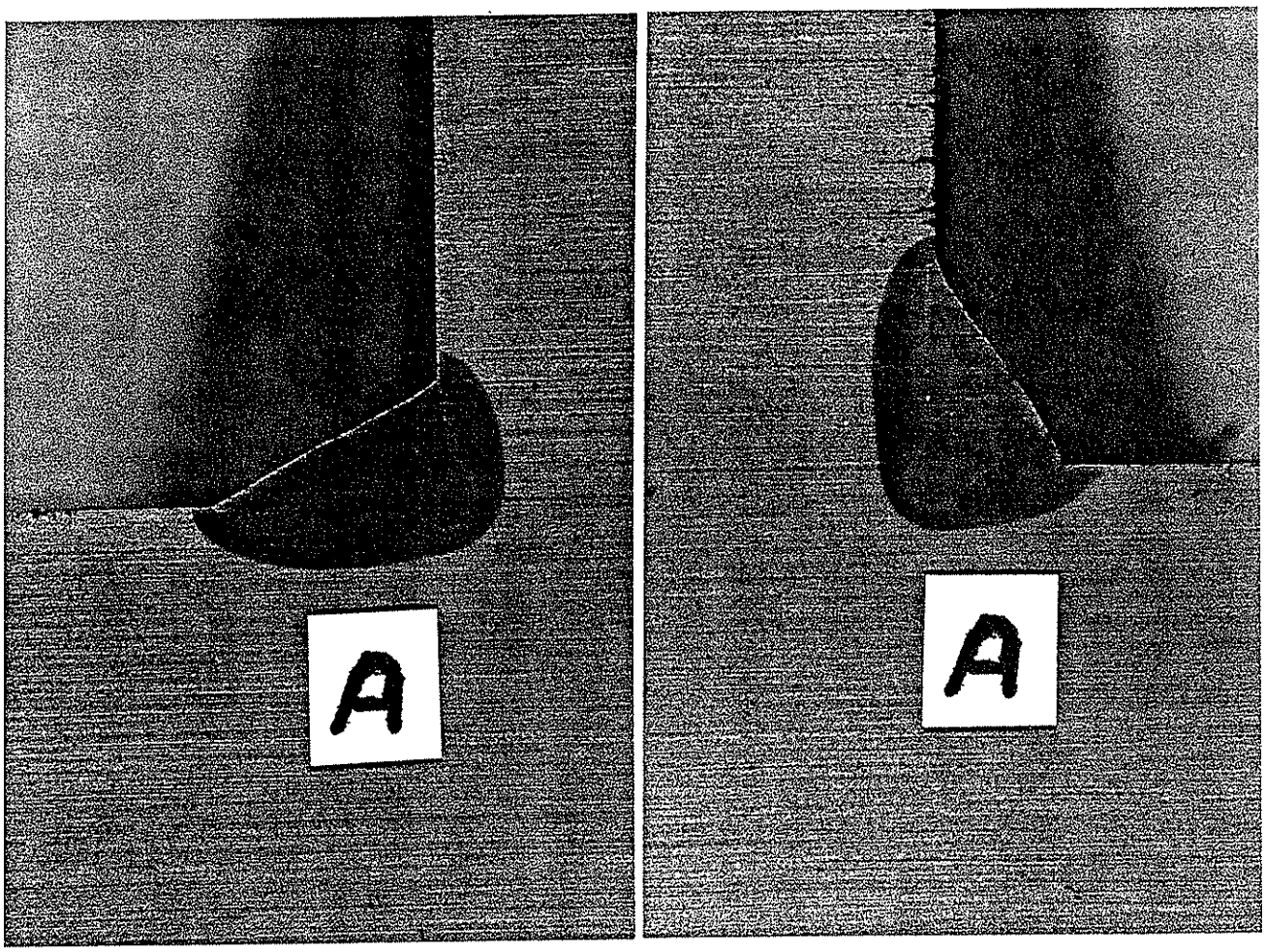


Figure 18

Billet "A"

Enlargements of weldment section; 2 3/8 inches from front end.

Left: 1/4 inch intermittent.

Right: 1/4 inch continuous.

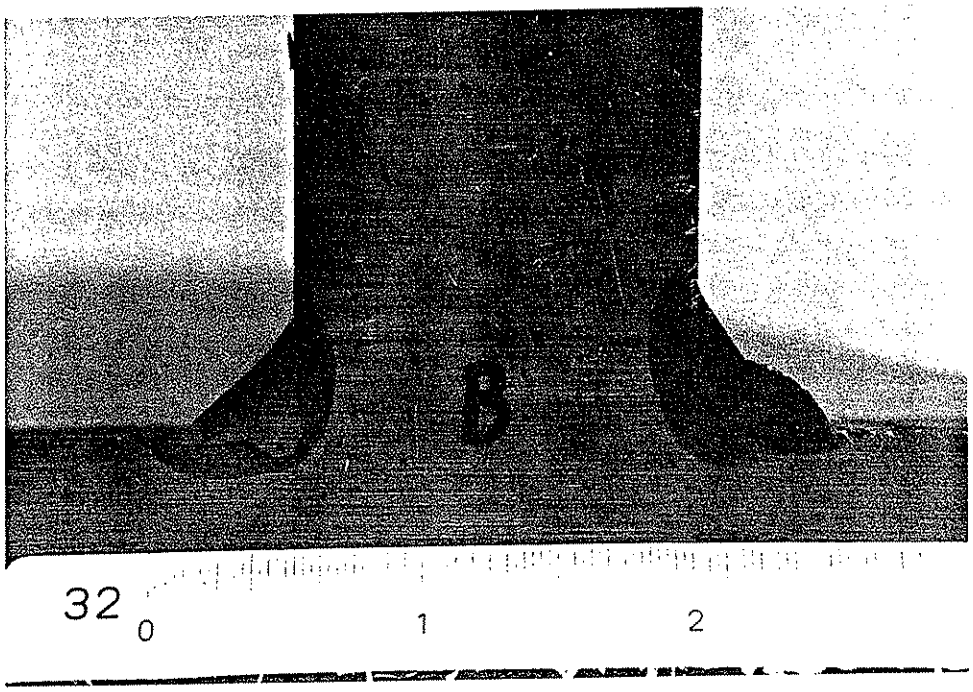


Figure 19

"Weldment Standard" section 2 3/8 inches from "front-end.

Billet "B" weldment

Left: 1/2 inch intermittent.

Right: 1/2 inch continuous.

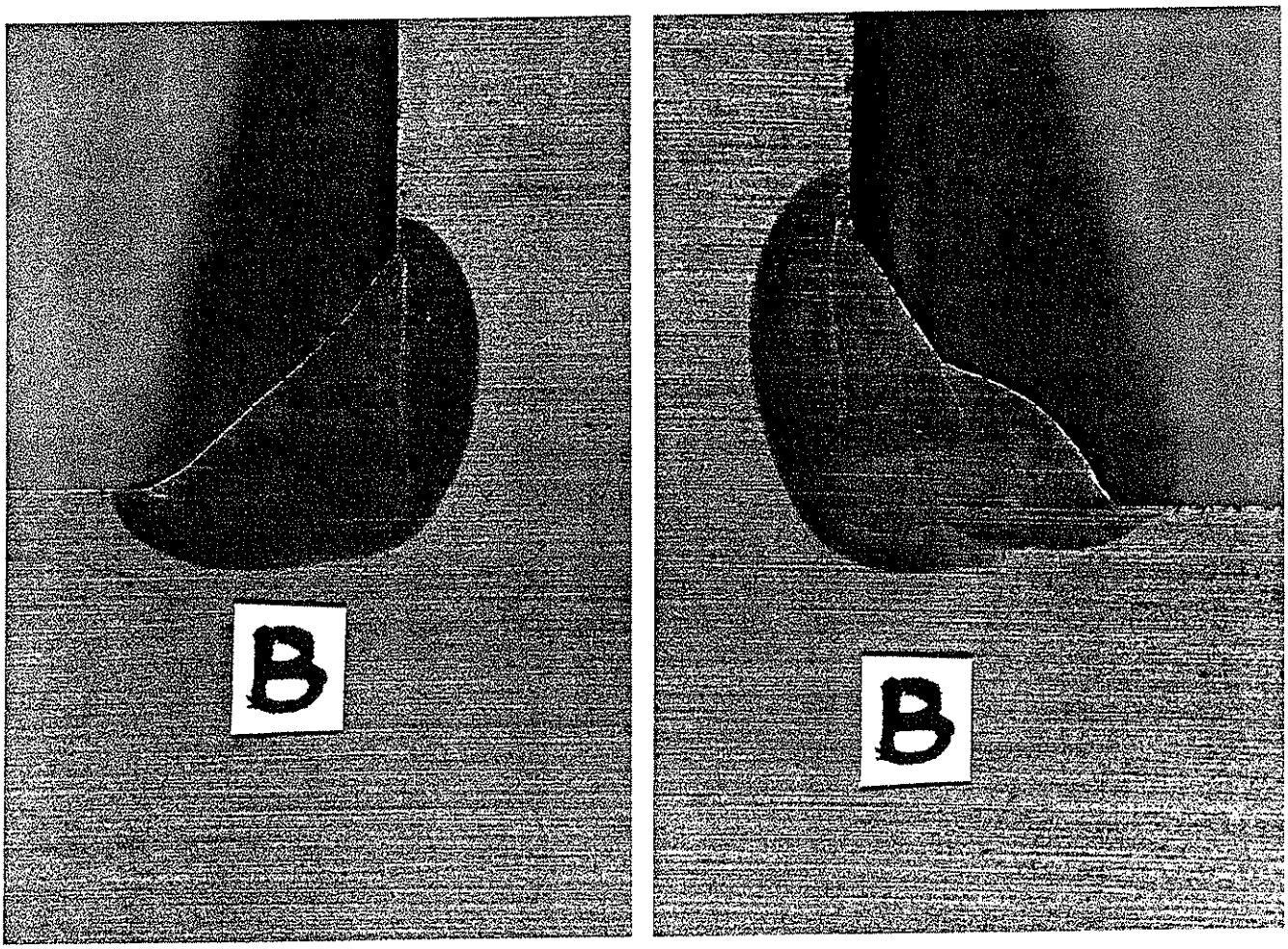


Figure 20

Billet "B"

Enlargements of weldment section 2 3/8 inches from front end.

Left: 1/2 inch intermittent.

Right: 1/2 inch continuous.

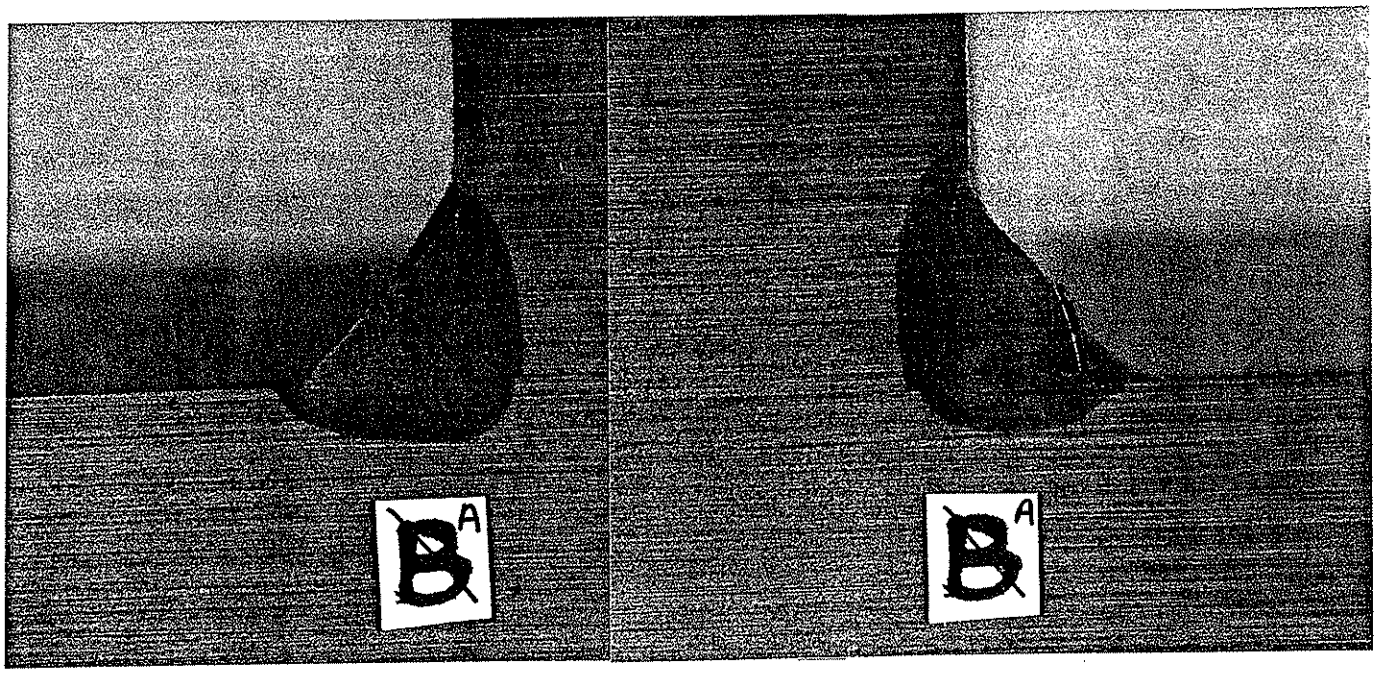


Figure 22

Billet "A"

Enlargements of weldment section 8 1/2 inches from front end

Left: 1/4 inch continuous.

Right: 1/4 inch intermittent.

NOTE: Photographic negatives 7/90/7-6(R)& 7/90/7-8 are incorrectly labeled.

"A" is the correct designation

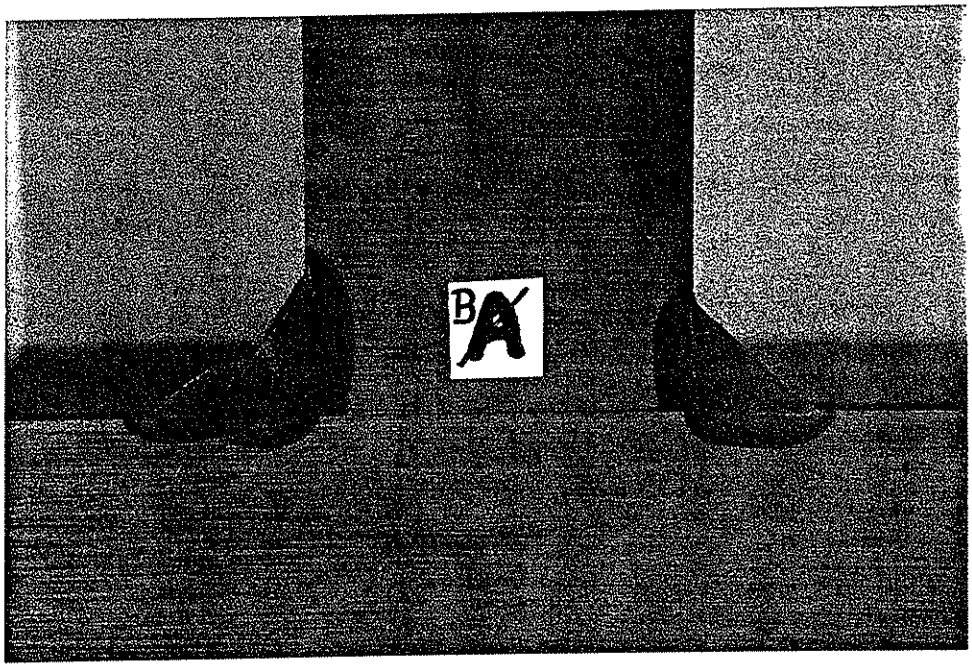


Figure 23

"Weldment Standard" section 8 1/2 inches from front-end.

Billet "B" weldment

Left: 1/2 inch continuous.

Right: 1/2 inch intermittent.

NOTE: Photographic negative 7/90/7-2 is incorrectly labeled.

"B" is the correct designation.

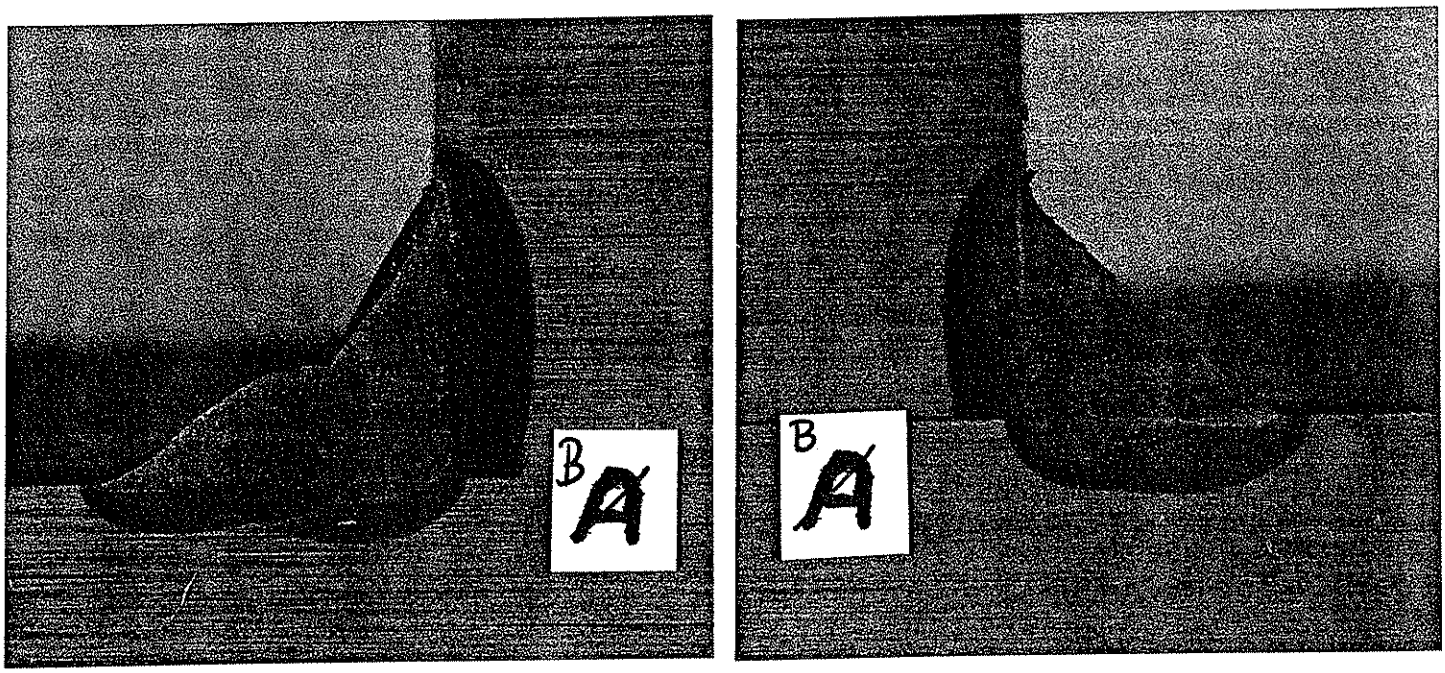


Figure 24

Billet "B" weldment

Enlargements of weldment section 8 1/2 inches from front end

Left: 1/2 inch continuous.

Right: 1/2 inch intermittent.

Floor Anchor Identification

Each floor anchor was assigned a unique identification number using a row and column matrix system shown in Figure 25. Identification of welds on each billet is detailed in Figure 26

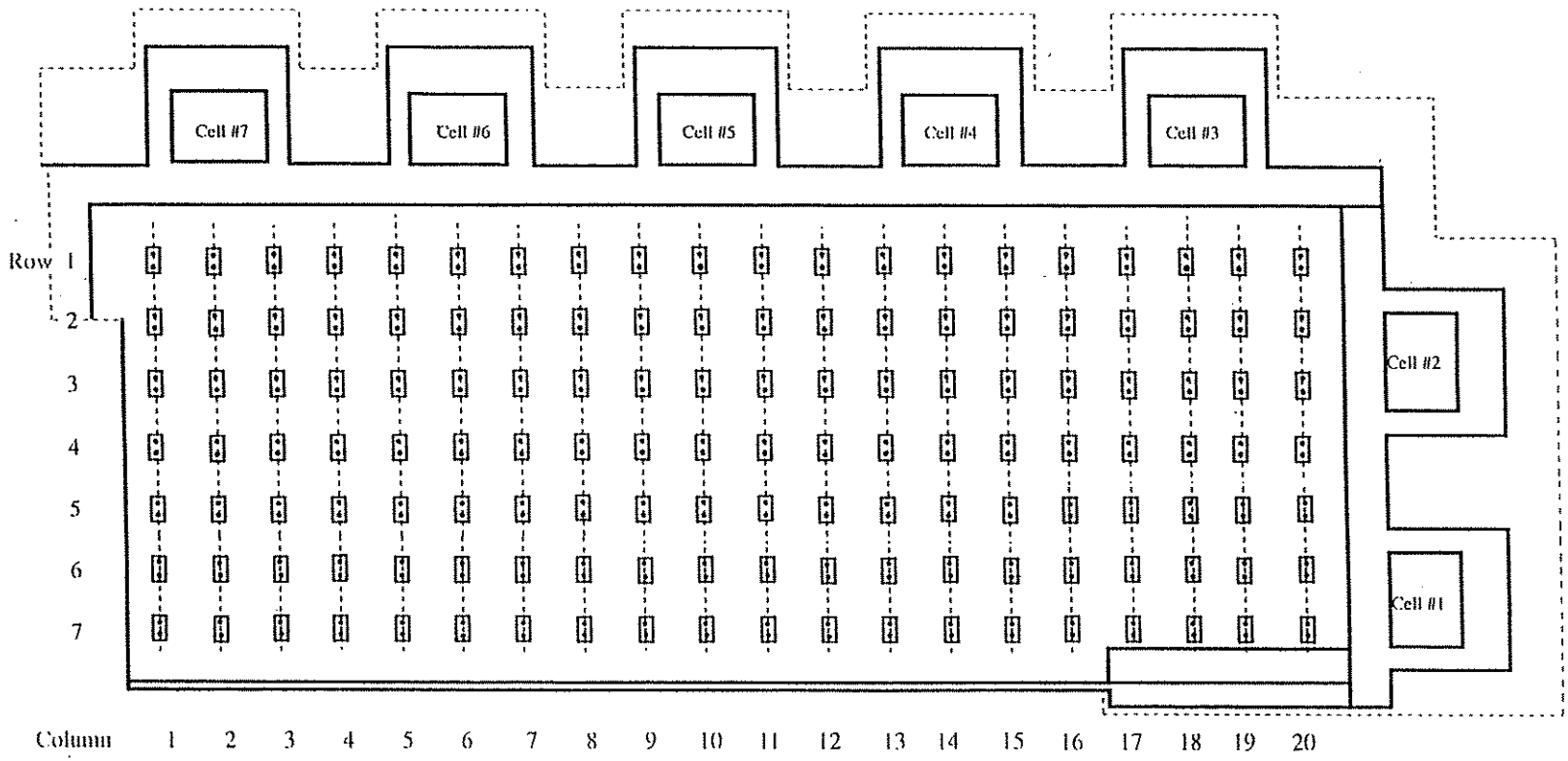
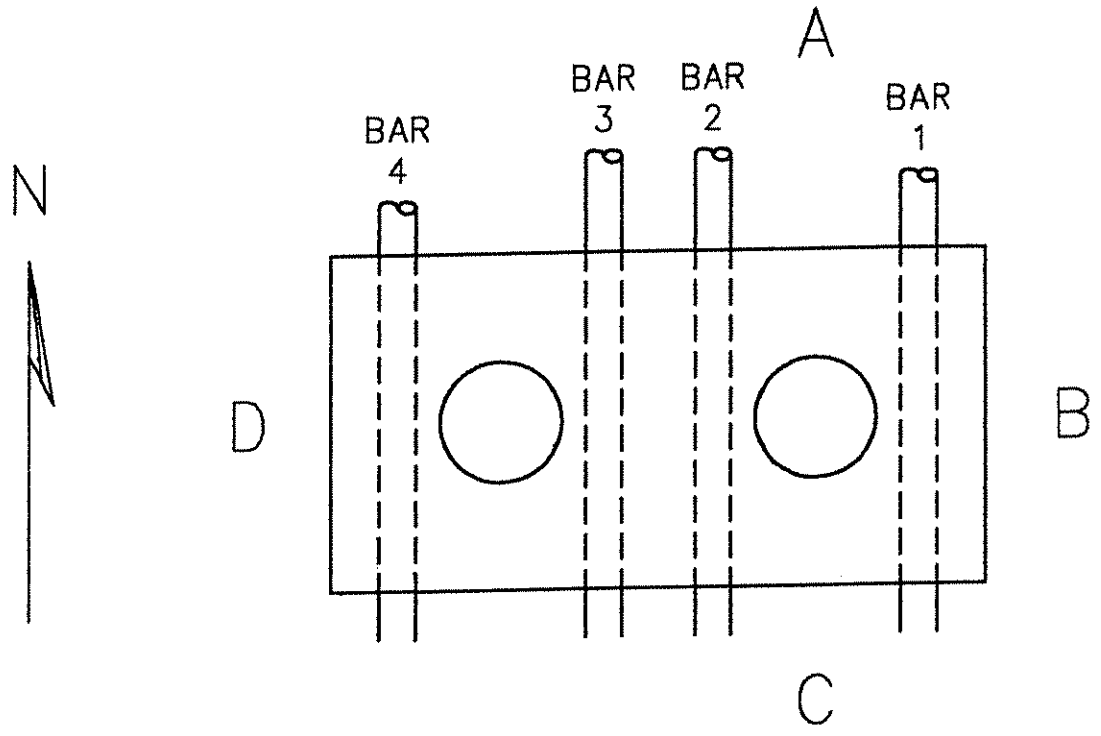


Figure 25

Matrix Row and Column Identification system for Floor Anchor Plates.



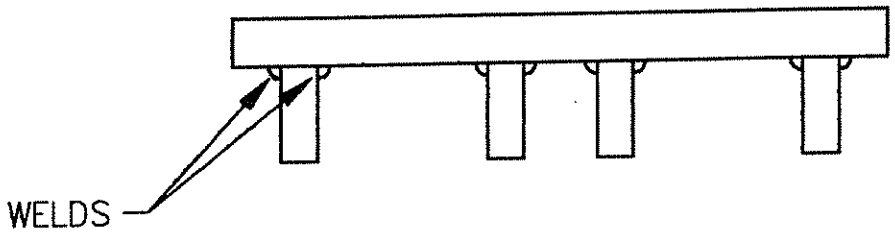


Figure 26

C-Scan Plate Layout.

Weld Identification System for C-Scan Charts.

Test Results and Observations

Twenty-one anchor plates were scanned during this investigation. While establishing the Test Protocol, it was found that; adhered to the top surface of the plates, was a very hard and very thick mill scale. The severe density and thickness of this mill scale required a very high gain on the ultrasonic set-up for penetration of the sonic wave. Setting the gain high enough to penetrate the mill scale resulted in gross unacceptable distortions. The test protocol was modified by grinding off the mill scale from each evaluated anchor plate. The weld sizes and lengths of each weldment evaluated are found in Table 1.

None of the 21 anchor plates evaluated during the course of this investigation have fully effective welds as required by the issued-for-construction drawings. The actual capacity of those anchor plates used should be evaluated for each future test setup in the ATLSS Facility.

As the plan view in Figure 2 indicates, there are 112 inches of length available for placing a weld along each side of the 4 billets. Note, as shown in Figure 2, that welds are required across the top of the 1 1/2 inch wide billet , however, none of the billet/anchor plate weldments were welded in this manner. In the writer's opinion and from a purely practical point of view, welding across this small distance will not result in defect-free welds without qualified visual inspection. In addition, AWS D1.1 Sec.9.15 does not allow fillet welds to be tied together when they are on opposite sides of a common plane of contact. Editorial comments aside, the static load capacity using E70 electrodes and specified 1/2 inch fillet welds is:

$$7.42 \text{ Kips/inch} * 112 \text{ inch} = 931. \text{ Kips}$$

The most severe reduction in static capacity occurs with Plate C20-R1. Table 1 shows that each billet-to-anchor plate is 1/2 inch in size, however, the total weld length is only 32 inches. Thus the allowable static weld capacity is:

7.42 Kip/inch * 32 inches = 237. Kips

Three factors contributed to production of the poor quality and under-sized welds investigated in this report:

1) The Construction Manager did not provide qualified inspection of the sub-contractor which fabricated the Floor Anchor Plate-Billet Modules.
2) "Pre-Qualified" weld procedures were inadequate in providing sufficient voltage and amperage to penetrate the extremely hard and thick mill scale which was encountered during the ultrasound investigation.
3) The weldment detail, provided by the designers, did not provide enough space to apply continuous welds. This is evident from examining Figure 2. In order to install the shear studs in the position shown, would require welding of the studs when the billets were not yet welded to the anchor plate. Once the billets are welded to the anchor plate, the space between the billets is not wide enough for a stud welding gun and the stud. Placing the shear studs which are located at the Floor Anchor Plate to the outside of the fixture would resolve this fabrication problem.

The calculated static shear capacity of the 21 billet-anchor plate weldments are detailed in Table 1. For those connections which contain different weld sizes, the shear capacity is controlled and limited by the smallest weld size of the group.

PLATE #	BAR #	WELD IDENT	WELD SIZE	LENGTH OF WELD	STATIC CAPACITY OF WELD
C20	1	B	½	2,1,2¼	240.K
R1	1	D	½	2,2	Based on
	2	B	½	2,2	½ inch
	2	D	½	2,2	Effective Weld
	3	B	½	2,2	
	3	D	½	2,2	
	4	B	½	2,1 7/8	
	4	D	½	1¾,1½	
C20	2	B	3/8	14	Not Determined
R2	2	D	3/8	14	Because Bar No. 1
	3	B	3/8	14	was not Scanned
	3	D	3/8	14	
	4	B	3/8	14	
	4	D	3/8	14	
C15	1	B	7/16	14	515.K
R4	1	D	7/16	14	Based on
	2	B	5/16	14	5/16 inch
	2	D	5/16	14	Effective Weld
	3	B	5/16	14	
	3	D	5/16	14	
	4	B	5/16	13	
	4	D	5/16	14	

Table 1 (page 1 of 7)

PLATE #	BAR #	WELD IDENT	WELD SIZE	LENGTH OF WELD	STATIC CAPACITY OF WELD
C15	1	B	¼	14	409.K
R5	1	D	¼	14	Based on
	2	B	¼	14	¼ inch
	2	D	¼	14	Effective Weld
	3	B	¼	14	
	3	D	¼	14	
	4	B	¼	14	
	4	D	¼	14	
C15	1	B	¼	14	383.K
R3	1	D	1/16-¼	14	Based on
	2	B	¼	14	¼ inch
	2	D	¼	14	Effective Weld
	3	B	5/16	14	
	3	D	1/16-¼	14	
	4	B	1/8-¼	14	
	4	D	¼	14	
C15	1	B	7/16	14	411.K
R6	1	D	7/16	14	Based on
	2	B	½	14	¼ inch
	2	D	½	14	Effective Weld
	3	B	¼-7/16	14	
	3	D	¼-7/16	14	
	4	B	¼-5/16	13	
	4	D	5/16	14	

Table 1 (page 2 of 7)

PLATE #	BAR #	WELD IDENT	WELD SIZE	LENGTH OF WELD	STATIC CAPACITY OF WELD
C20	1	B	5/16	14	411.K
R3	1	D	½	14	Based on
	2	B	5/16	14	¼ inch
	2	D	5/16	14	Effective Weld
	3	B	¼	13	
	3	D	5/16	14	
	4	B	7/16	14	
	4	D	7/16	14	
C16	1	B	¼	9	258.K
R3	1	D	¼	12	Based on
	2	B	3/16	14	3/16 inch
	2	D	3/16	10	Effective Weld
	3	B	¼	14	
	3	D	3/16-¼	12	
	4	B	¼	13	
	4	D	1/8-¼	9	
C16	1	B	½	14	519.K
R4	1	D	7/16	14	Based on
	2	B	5/16	14	5/16 inch
	2	D	5/16	14	Effective Weld
	3	B	7/16	14	
	3	D	7/16	14	
	4	B	5/16	14	
	4	D	5/16	14	

Table 1 (page 3 of 7)

PLATE #	BAR #	WELD IDENT	WELD SIZE	LENGTH OF WELD	STATIC CAPACITY OF WELD
C16	1	B	5/16	14	200.K
R5	1	D	5/16	14	Based on
	2	B	¼	12	1/8 inch
	2	D	1/8-¼	12	Effective Weld
	3	B	¼	14	
	3	D	1/8-¼	14	
	4	B	5/16	14	
	4	D	¼	14	
C16	1	B	9/16	14	415.K
R6	1	D	½	14	Based on
	2	B	5/16	14	¼ inch
	2	D	¼	14	Effective Weld
	3	B	¼	14	
	3	D	¼	14	
	4	B	¼	14	
	4	D	5/16	14	
C16	1	B	¼	8	393.K
R7	1	D	¼	14	Based on
	2	B	¼	14	¼ inch
	2	D	5/16	14	Effective Weld
	3	B	¼	14	
	3	D	1/8-¼	14	
	4	B	¼	14	
	4	D	¼	14	

Table 1 (page 4 of 7)

PLATE #	BAR #	WELD IDENT	WELD SIZE	LENGTH OF WELD	STATIC CAPACITY OF WELD
C7	1	B	5/16	14	515.K
R5	1	D	5/16	14	Based on
	2	B	7/16	14	5/16 inch
	2	D	7/16	14	Effective Weld
	3	B	5/16	14	
	3	D	5/16	13	
	4	B	5/16	14	
	4	D	7/16	14	
C7	1	B	5/16	13	408.K
R6	1	D	¼	14	Based on
	2	B	5/16	14	¼ inch
	2	D	5/16	14	Effective Weld
	3	B	¼-5/16	13	
	3	D	¼	14	
	4	B	5/16	14	
	4	D	¼	14	
C7	1	B	5/16	14	404.K
R7	1	D	½	14	Based on
	2	B	5/16	14	¼ inch
	2	D	¼	14	Effective Weld
	3	B	1/16-¼	11 @ ¼	
	3	D	5/16	14	
	4	B	5/16	14	
	4	D	5/16	14	

Table 1 (page 5 of 7)

PLATE #	BAR #	WELD IDENT	WELD SIZE	LENGTH OF WELD	STATIC CAPACITY OF WELD
C7	1	B	¼-5/16	12	186.K
R4	1	D	¼	11	Based on
	2	B	¼	14	1/8 inch
	2	D	3/16-¼	14	Effective Weld
	3	B	5/16	14	Due to "Spotty" Nature
	3	D	5/16	14	of Weld Image
	4	B	1/8-¼	14	
	4	D	1/16-¼	7 @ ¼	
C8	1	B	¼	14	415.K
R3	1	D	5/16	14	Based on
	2	B	5/16	14	¼ inch
	2	D	7/16	14	Effective Weld
	3	B	7/16	14	
	3	D	½	14	
	4	B	5/16	14	
	4	D	5/16	14	
C8	1	B	7/16	14	266.K
R5	1	D	7/16	14	Based on
	2	B	¼	14	3/16 inch
	2	D	5/16	14	Effective Weld
	3	B	¼	13	
	3	D	5/16	13	
	4	B	3/16	8	
	4	D	3/16	6	

Table 1 (page 6 of 7)

PLATE #	BAR #	WELD IDENT	WELD SIZE	LENGTH OF WELD	STATIC CAPACITY OF WELD
C8	1	B	¼	12.5	396.K
R6	1	D	¼	12	Based on
	2	B	5/16	14	¼ inch
	2	D	5/16	14	Effective Weld
	3	B	¼	13	
	3	D	¼	13.5	
	4	B	5/16	14	
	4	D	¼	14	
C8	1	B	¼	9	338.K
R4	1	D	¼	11.5	Based on
	2	B	¼	6	¼ inch
	2	D	5/16	8.75	Effective Weld
	3	B	5/16	14	
	3	D	7/16	14	
	4	B	¼	14	
	4	D	¼	14	
C8	1	B	5/16	14	415.K
R7	1	D	¼	14	Based on
	2	B	¼-5/16	14	¼ inch
	2	D	5/16-7/16	14	Effective Weld
	3	B	3/8	14	
	3	D	7/16	14	
	4	B	5/16	14	
	4	D	5/16	14	

Table 1 (page 7 of 7)